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THE RELATION OF GENETICS TO PHYSIOLOGY AND MEDICINE

NOBEL LECTURE, PRESENTED IN STOCKHOLM ON JUNE 4, 1934

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THE study of heredity, now called genetics, has undergone such an extraordinary development in the present century, both in theory and in practice, that it is not possible in a short address to review even briefly all its outstanding achievements. At most I can do no more than take up a few topics for discussion.

Since the group of men with whom I have worked for twenty years has been interested for the most part in the chromosome-mechanism of heredity, I shall first briefly describe the relation between the facts of heredity and the theory of the gene. Then I should like to discuss one of the physiological problems implied in the theory of the gene; and finally, I hope to say a few words about the applications of genetics to medicine.

The modern theory of genetics dates from the opening years of the present century, with the discovery of Mendel's long-lost paper that had been overlooked for thirty-five years. The data obtained by de Vries in Holland, Correns in Germany and Tschermak in Austria showed that Mendel's laws are not confined to garden peas, but apply to other plants. A year or two later the work of Bateson and Punnett in England and Cuénot in France made it evident that the same laws apply to animals.

In 1902 a young student, William Sutton, working in the laboratory of E. B. Wilson, pointed out clearly and completely that the known behavior of the chromosomes at the time of maturation of the germ-cells furnishes us with a mechanism that accounts for the kind of separation of the hereditary units postulated in Mendel's theory.

The discovery of a mechanism, that suffices to explain both the first and the second law of Mendel, has had far-reaching consequences for genetic theory, especially in relation to the discovery of additional laws; because the recognition of a mechanism that can be seen and followed demands that any extension of Mendel's theories must conform to such a recognized mechanism; and also because the apparent exceptions to Mendel's laws, that came to light before long, might, in the absence of a known mechanism, have called forth purely fictitious modifications of Mendel's laws or even seemed to invalidate their generality. We now know that some of these "exceptions" are due to newly discovered and demonstrable properties of the chromosome mechanism, and others to recognizable irregularities in the machine.

Mendel knew of no processes taking place in the formation of pollen and egg-

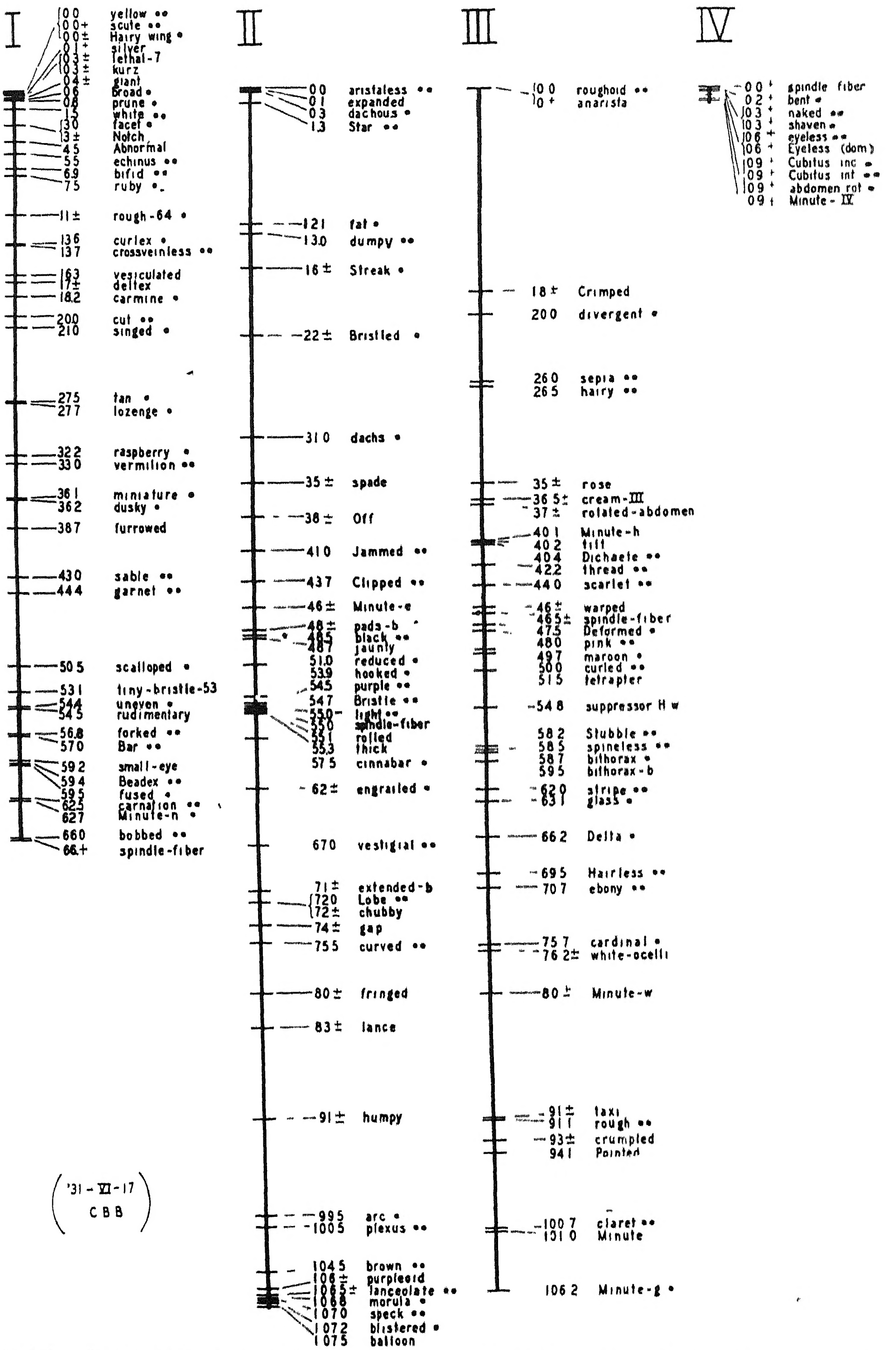


FIG 1. GENETIC MAP OF THE FOUR CHROMOSOMES OF DROSOPHILA MELANOGASTER SHOWING THE LINEAR ORDER AND RELATIVE DISTANCE APART OF THE GENES. (AFTER BRIDGES.)

cell that could furnish a basis for his primary assumption that the hereditary elements separate in the germ-cells in such a way that each ripe germ-cell comes to contain only one of each kind of element: but he justified the validity of this assumption by putting it to a crucial test. His analysis was a wonderful feat of reasoning. He verified his reasoning by the recognized experimental procedure of science.

As a matter of fact it would not have been possible in Mendel's time to give an objective demonstration of the basic mechanism involved in the separation of the hereditary elements in the germ-cells. The preparation for this demonstration took all the thirty-five years between Mendel's paper in 1865 and 1900. It is here that the names of the most prominent European cytologists stand out as the discoverers of the rôle of the chromosomes in the maturation of the germ-cells. It is largely a result of their work that it was possible in 1902 to relate the well-known cytological evidence to Mendel's laws. So much in retrospect.

The most significant additions that have been made to Mendel's two laws may be called linkage and crossing over. In 1906 Bateson and Punnett reported a two-factor case in sweet peas that did not give the expected ratio for two pairs of characters entering the cross at the same time.

By 1911 two genes had been found in Drosophila that gave sex-linked inheritance. It had earlier been shown that such genes lie in the X-chromosomes. Ratios were found in the second generation that did not conform to Mendel's second law when these two pairs of characters are present, and the suggestion was made that the ratios in such cases could be explained on the basis of interchange between the two X-chromosomes in the female. It was also pointed out that the further apart the genes for such characters happen to lie in the chromosome, the greater the chance for interchange to take place. This would give the approximate location of the genes with respect to other genes. By further extension and clarification of this idea it became possible, as more evidence accumulated, to demonstrate that the genes lie in a single line in each chromosome.

Two years previously (1909) a Belgian investigator, Janssens, had described a phenomenon in the conjugating chromosomes of a salamander, Batracoseps, which he interpreted to mean that interchanges take place between homologous chromosomes. This he called chiasmatypie—a phenomenon that has occupied the attention of cytologists down to the present day. Janssens' observations were destined shortly to supply an objective support to the demonstration of genetic interchange between linked genes carried in the sex chromosomes of the female Drosophila.

To-day we arrange the genes in a chart or map, Fig. 1. The numbers attached express the distance of each gene from some arbitrary point taken as zero. These numbers make it possible to foretell how any new character that may appear will be inherited with respect to all other characters, as soon as its crossing over value with respect to any other two characters is determined. This ability to predict would in itself justify the construction of such maps, even if there were no other facts concerning the location of the genes; but there is to-day direct evidence in support of the view that genes lie in a serial order in the chromosomes.

What are the Genes?

What is the nature of the elements of heredity that Mendel postulated as purely theoretical units? What are genes? Now that we locate them in the chromosomes are we justified in regarding them as material units; as chemical bodies of a higher order than molecules?

Frankly, these are questions with which the working geneticist has not much concern himself, except now and then to speculate as to the nature of the postulated elements. There is no consensus of opinion amongst geneticists as to what the genes are—whether they are real or purely fictitious—because at the level at which the genetic experiments lie it does not make the slightest difference whether the gene is a hypothetical unit or whether the gene is a material particle. In either case the unit is associated with a specific chromosome, and can be localized there

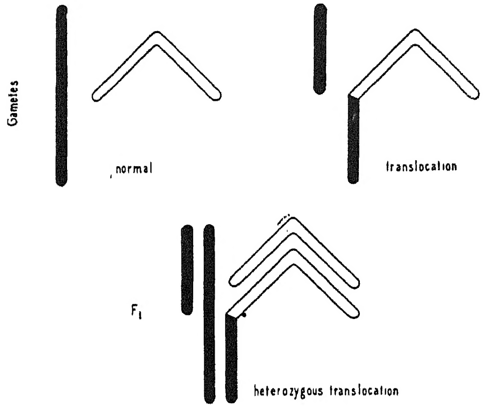


FIG. 2. DIAGRAM TO ILLUSTRATE THE CASE WHEN A PIECE OF ONE CHROMOSOME (BLACK) HAS BEEN TRANSLOCATED TO ANOTHER CHROMOSOME (WHITE). IN THE LOWER PART OF THE FIGURE THE METHOD OF CONJUGATION OF THESE CHROMOSOMES IS SHOWN.

by purely genetic analysis. Hence, if the gene is a material unit, it is a piece of a chromosome; if it is a fictitious unit, it must be referred to a definite location in a chromosome—the same place as on the other hypothesis. Therefore, it makes no difference in the actual work in genetics which point of view is taken.

Between the characters that are used by the geneticist and the genes that the theory postulates lies the whole field of embryonic development, where the properties implicit in the genes become explicit in the protoplasm of the cells. Here we appear to approach a physiological problem, but one that is new and strange to the classical physiology of the schools.

We ascribe certain general properties to the genes, in part from genetic evidence and in part from microscopical observations. These properties we may next consider.

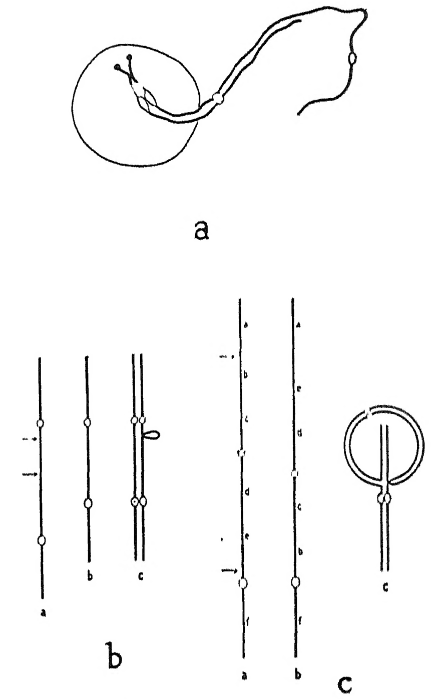


FIG. 3. (a) TWO CONJUGATING CHROMOSOMES OF INDIAN CORN (AFTER MCCLINTOCK). ONE CHROMOSOME HAS A TERMINAL DEFICIENCY. (b) TWO CHROMOSOMES OF INDIAN CORN, ONE HAVING A DEFICIENCY NEAR ITS MIDDLE. WHEN THESE TWO CHROMOSOMES CONJUGATE THERE IS A LOOP IN THE LONGER CHROMOSOME OPPOSITE THE DEFICIENCY IN THE OTHER ONE. (c) TWO CHROMOSOMES OF INDIAN CORN, ONE HAVING A LONG INVERTED REGION. WHEN THEY CONJUGATE THEY COME TOGETHER AS SHOWN IN THE FIGURE TO THE RIGHT, LIKE GENES COMING TOGETHER.

Since chromosomes divide in such a way that the line of genes is split (each daughter chromosome receiving exactly half of the original line) we can scarcely avoid the inference that the genes divide into exactly equal parts; but just how

this takes place is not known. The analogy of cell-division creates a presumption that the gene divides in the same way, but we should not forget that the relatively gross process involved in cell-division may seem quite inadequate to cover the refined separation of the gene into equal halves. As we do not know of any comparable division phenomena in organic molecules, we must also be careful in ascribing a simple molecular constitution to the gene. On the other hand, the elaborate chains of molecules built up in organic material may give us, some day, a better opportunity to picture the molecular or aggregate structure of the gene and furnish a clue concerning its mode of division.

Since by infinite subdivisions the genes do not diminish in size or alter as to their properties, they must, in some sense, compensate by growing between successive divisions. We might call this property autocatalysis, but, since we do not know how the gene grows, it is somewhat hazardous to assume that its property of growth after division is the same process that the chemist calls autocatalytic. The comparison is at present too vague to be reliable.

The relative stability of the gene is an inference from genetic evidence. For thousands—perhaps many millions—of subdivisions of its material it remains constant. Nevertheless, on rare occasions, it may change. We call this change a *mutation,* following de Vries' terminology. The point to emphasize here is that the mutated gene retains, in the great majority of cases studied, the property of growth and division, and more important still the property of stability. It is, however, not necessary to assume, either for the original genes or for the mutated genes, that they are all equally stable. In fact, there is a good deal of evidence for the view that some genes mutate oftener than others, and in a few cases the phenomenon is not infrequent, both in the germ-cells and in somatic tissues. Here the significant fact is that these repetitional changes are in definite and specific directions.

The constancy of position of genes with respect to other genes in linear order in the chromosomes is deducible, both from genetic evidence and from cytological observations. Whether the relative position is no more than a *historical accident* or whether it is due to some relation between each gene and its neighbors can not be definitely stated. But the evidence from the dislocation of a fragment of the chromosome and its reattachment to another one indicates that accident rather than mutual interaction has determined their present location: for, when a piece of one chromosome becomes attached to the end of a chain of genes of another chromosome or when a section of a chromosome becomes inverted, the genes in the new position hold as fast together as they do in the normal chromosome.

There is one point of great interest. So far as we can judge from the action of mutated genes, the kind of effect produced has as a rule no relation to location of the gene in the chromosome. A gene may produce its chief effect on the eye-color, while one nearby may affect the wing-structure, and a third, in the same region, the fertility of the male or of the female. Moreover, genes in different chromosomes may produce almost identical effects on the same organs. One may say, then, that the position of the genes in the hereditary material is inconsequential in relation to the effects that they produce. This leads to a consideration which is more directly significant for the physiology of development.

In the earlier days of genetics it was customary to speak of unit characters in heredity, because certain contrasted characters, rather clearly defined, furnished the data for the Mendelian ratios.

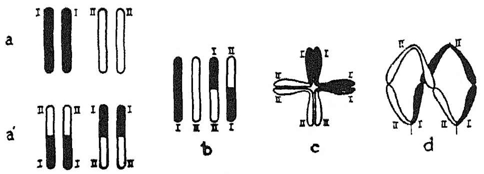


FIG. 4. DIAGRAM OF OENOTHERA CHROMOSOMES ILLUSTRATING THE CONFIGURATION OF CHROMOSOMES (c AND d) WHEN THERE HAS BEEN AN EXCHANGE BETWEEN DIFFERENT CHROMOSOMES AS INDICATED IN THE FIGURE BY THE BLACK AND WHITE. IN a AND a′ AN EXCHANGE BETWEEN CHROMOSOMES I AND II IS SHOWN. IN b THE CHROMOSOME GROUP IS DRAWN, IN WHICH THERE ARE TWO INTERCHANGED CHROMOSOMES AND TWO WHOLE CHROMOSOMES. IN c THE COMING TOGETHER OF THESE FOUR CHROMOSOMES IS SHOWN, AND IN d THE RESULTS OF THE OPENING OUT OF THIS CROSS INTO A TWISTED RING. CHROMOSOME PAIRS, THAT CAME IN TOGETHER, PASS TO OPPOSITE POLES.

Certain students of genetics inferred that the Mendelian units responsible for the selected character were genes producing only a single effect. This was careless logic. It took a good deal of hammering to get rid of this erroneous idea. As facts accumulated it became evident that each gene produces not a single effect, but in some cases a multitude of effects on the characters of the individual. It is true that in most genetic work only one of these character-effects is selected for study—the one that is most sharply defined and separable from its contrasted character—but in most cases minor differences also are recognizable that are just as much the product of the same gene as is the major effect. In fact, the major difference selected for classification of the contrasted character-pairs may be of small importance for the welfare of the individual, while some of the concomitant effects may be of vital importance for the economy of the individual, affecting its vitality, its length of life or its fertility. I need not dwell at length on these relations because they are recognized to-day by all geneticists. It is important, nevertheless, to take cognizance of them, because the whole problem of the physiology of development is involved.

The coming together of the chromosomes at the maturation division, and their subsequent movement apart to opposite poles of the meiotic figure, insures the regular distribution of one set of chromosomes to each daughter-cell and the fulfilment of Mendel's second law. These movements have the appearance of physical events. Cytologists speak of

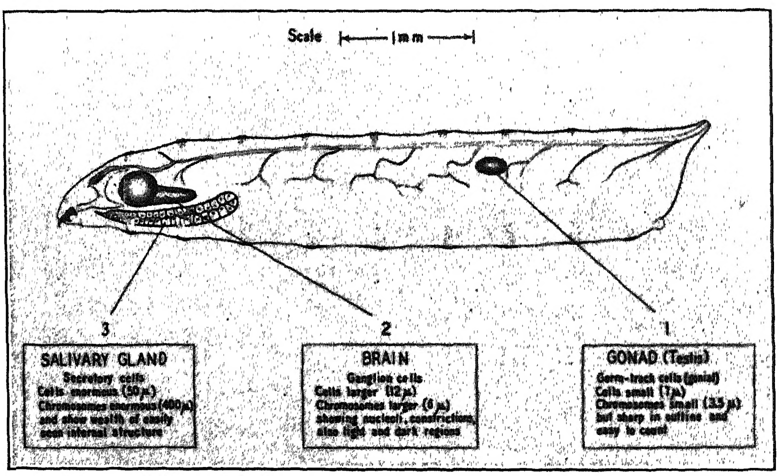


FIG. 5. DIAGRAM OF LARVA OF DROSOPHILA MELANOGASTER SHOWING THE GONAD, BRAIN AND ONE OF THE SALIVARY GLANDS.

these two phenomena as *attraction* and *repulsion* of the members of individual chromosomes, but we have no knowledge of the kind of physical processes involved. The terms attraction and repulsion are purely descriptive, and mean no more at present than that like chromosomes come together and later separate.

In earlier times, when the constitution of the chromosomes was not known, it was supposed that the chromosomes come together at random in pairs. There was the implication that any two chromosomes may mate. The comparison with conjugation of male and female protozoon, or egg and sperm-cell, was obvious, and since in all diploid cells one member of each pair of chromosomes has come from the father and one from the mother, it must have seemed that somehow maleness and femaleness are involved in the conjugation of the chromosomes also. But to-day we have abundant evidence to prove that this idea is entirely erroneous, since there are cases where both chromosomes that conjugate have come from the female, and even where both have been sister strands of the same chromosome.

Recent genetic analysis shows not only that the conjugating chromosomes are like chromosomes, *i.e.,* chains of the same genes, but also that very exact process is involved. The genes come together, point for point, unless some physical obstacle prevents. The last few years have furnished some beautiful illustrations showing that it is genes rather than whole chromosomes that come to lie side by side when the chromosomes come together. For example, occasionally a chromosome may have a piece broken off (Fig. 2, above) which becomes attached to another chromosome. A new linkage group is thus established. When conjugation takes place this piece has no corresponding piece in the sister chromosome. It has been shown (Fig. 2) that it then conjugates with that part of the parental chromosomes from which it came.

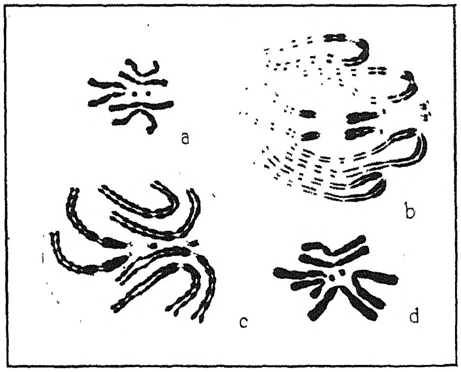
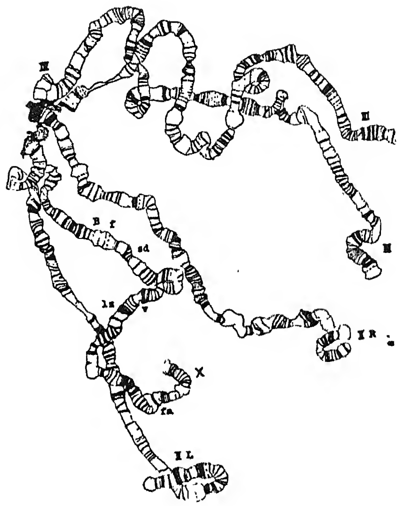
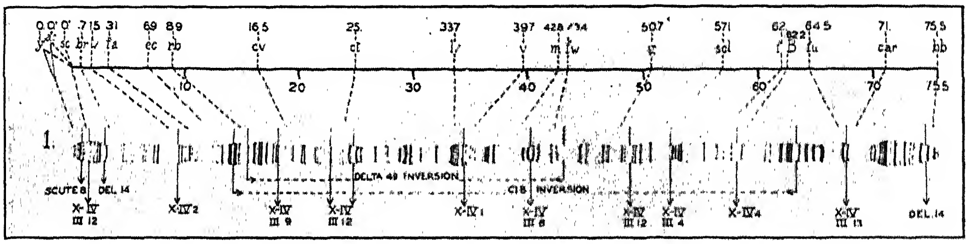


FIG. 6. THE RELATIVE SIZES OF THE CHROMOSOMES IN THE CELLS OF THE GONAD (a), OF THE GIANT GANGLION CELLS OF THE BRAIN (d), AND OF THE PROPHASE STAGE OF THE LATTER (b, c). IN a, A METAPHASE PLATE FROM THE GONAD IS SHOWN. IN b, A PROPHASE STAGE FROM A GANGLION CELL SHOWING THE BLACK (HEAVILY STAINED) INERT REGIONS OF THE CHROMOSOMES AND THE FAINTLY STAINED REGIONS CARRYING MOST OF THE GENES, ACCORDING TO HEITZ. IN c THE LATE PROPHASE OF THE SAME TYPE OF CELL IS SHOWN INTERMEDIATE BETWEEN b AND d. THE GENETIC REGION IS NOW STAINED. IN d (MALE) THE METAPHASE OF A GANGLION CELL HAS CHROMOSOMES LARGER THAN THOSE OF THE GONAD CELLS AS SHOWN IN a.

When a chromosome has lost one end, it conjugates with its mate only in part (Fig. 3a), *i.e.,* where like genes are present. When a chromosome has lost a small region, somewhere along its length, so that it is shorter than the original chromosome, the larger chromosome shows a loop which is opposite the region of deficiency in the shorter chromosome as shown in Fig. 3b. Thus like genes, or corresponding loci, are enabled to come together through the rest of the chromosome. More remarkable still is the case where the middle region of a chromosome has become turned around (inversion). When such a chromosome is brought together with its normal homologue, as shown in Fig. 3c, like regions come to-



a



b

FIG. 7. (a) THE CHROMOSOMES OF THE SALIVARY GLAND OF THE FEMALE LARVA OF DROSOPHILA MELANOGASTER (AFTER PAINTER). THE TWO X-CHROMOSOMES ARE FUSED INTO A SINGLE BODY. THIS CHROMOSOME IS ATTACHED AT ONE END TO THE COMMON CHROMOCENTER AT ITS ATTACHMENT END. THE 2D AND 3D CHROMOSOMES HAVE THE ATTACHMENT POINT NEAR THE MIDDLE AND ARE FUSED WITH THE COMMON CHROMOCENTER AT THIS POINT, LEAVING TWO FREE ENDS OF EACH CHROMOSOME. LIKE LIMBS OF EACH OF THESE FREE ENDS ARE FUSED, GIVING FOUR FREE ENDS IN ALL. (b) THE BANDED SALIVARY X-CHROMOSOME OF DROSOPHILA MELANOGASTER IS BELOW, WITH THE GENETIC MAP ABOVE. OBLIQUE BROKEN LINES CONNECT REGIONS OF THE GENETIC MAP WITH CORRESPONDING OR HOMOLOGOUS REGIONS OF THE SALIVARY CHROMOSOME.

gether by the inverted piece reversing itself, so to speak, so that like genes come together as shown to the right in Fig. 3c. In this same connection the conjugation of the chromosomes in species of Oenothera (Fig. 4) furnish beautiful examples of the way in which like series of genes find each other, even when halves of different chromosomes have been interchanged.

The very recent work of Heitz, Painter and Bridges has brought to light some astonishing evidence relating to the constitution of the chromosomes in the salivary glands of Drosophila, Figs. 5–10.

The nuclei of the cells of the salivary glands of the old larvae are very large and their contained chromosomes may be 70 to 150 times as long as those of the ordinary chromosomes in process of division. Heitz has shown that there are regions of some of the chromosomes of the ganglion cells—more especially of the X and the Y chromosomes—that stain deeply, and other regions faintly (Fig. 6) and that these regions cor-

respond to regions of the genetic map that do not and do contain genes. Painter has made the further important contribution that the series of bands of the salivary chromosomes can be homologized with the genetically known series of genes of the linkage maps (Fig. 7, a, b), and that the empty regions of the X and Y do not have the banded structure. He has further shown that when a part of the linkage map is reversed the sequence of the bands is also reversed; that when pieces are translocated they can be identified by characteristic bands: and that when pieces of linked genes are lost there is a corresponding loss of bands. Bridges has carried the analysis further by an intensive study of regions of particular chromosomes, and has shown a close agreement between bands and gene-location. With improved methods he has identified twice as many bands, thus making a more complete analysis of the relation of bands and gene-location. Thus, whether or not the bands are the actual genes, the evidence is clear in showing a remarkable agreement between the location of genes and the location of corresponding bands. The analysis of the banded structure has confirmed the genetic evidence, showing that when certain alterations of the order of the genes takes place there is a corresponding change in the sequence of the bands which holds for the finest details of the bands.

The number of chromosomes in the salivary nuclei is half that of the full number (as reported by Heitz) which Painter interprets as due to homologous chromosomes conjugating (Fig. 7a). Moreover, the bands in each of the component halves show an identical sequence which is strikingly evident when the halves are not closely apposed. It has been suggested by Bridges and by Koltzoff that homologous chromosomes have not only united, but that they have each divided two or three times, giving in some cases as many as 16 or 32 strands (Fig. 8). The bands may then be said to be composed each of 16 or 32 genes; or, if this identification of the bands as genes is questioned in so far as the genes are concerned, the bands are multiples of some kind of unit of which the chromosomes are composed.

A few examples may serve to illustrate

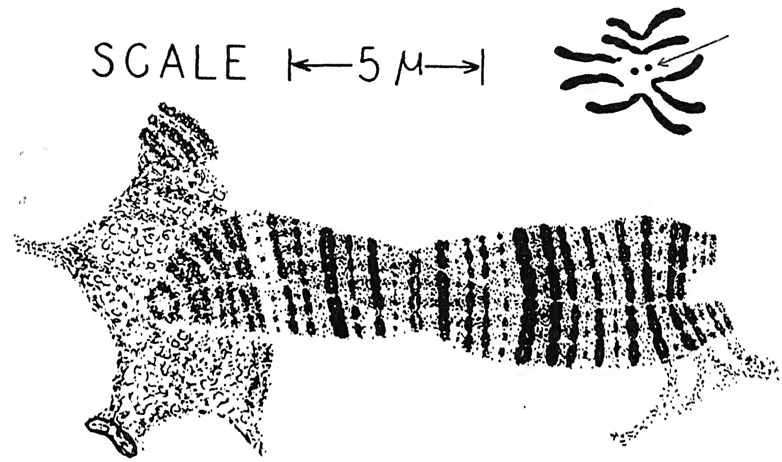


FIG. 8. ABOVE TO RIGHT THE FOUR PAIRS OF CHROMOSOMES OF DROSOPHILA IN THE METAPHASE STAGE FROM A CELL OF THE OVARY. THE TWO SMALLEST CHROMOSOMES ARE IN THE MIDDLE OF THE GROUP. THE SAME CHROMOSOMES FROM THE SALIVARY GLAND ARE DRAWN BELOW TO THE SAME SCALE (AFTER BRIDGES FROM THE JOURNAL OF HEREDITY).

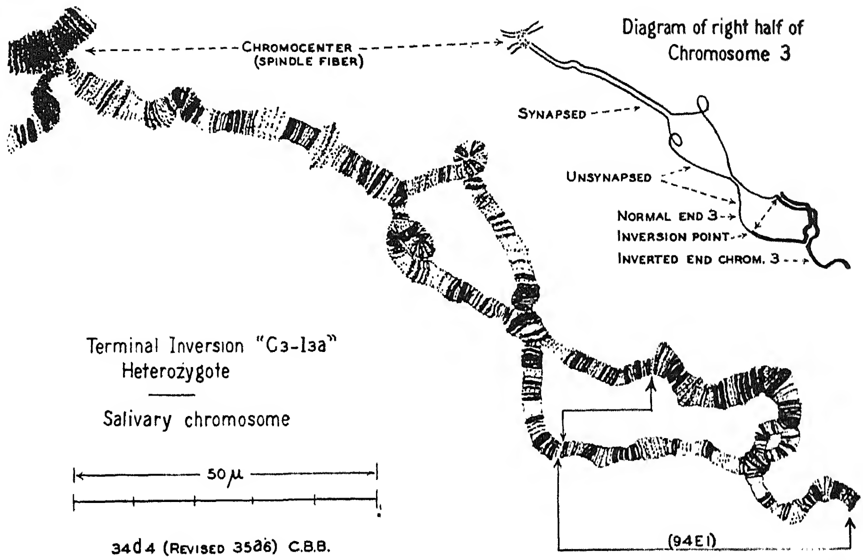


FIG. 9. SALIVARY GLAND PREPARATION OF RIGHT ARM OF THE THIRD CHROMOSOME, ILLUSTRATING A TERMINAL INVERSION IN ONE OF THE TWO COMPONENTS. THE TWO COMPONENTS ARE FUSED TOGETHER THROUGHOUT PART OF THEIR LENGTH AND ARE SEPARATE IN OTHER PARTS AS SHOWN IN THE SMALL DIAGRAM ABOVE AND TO RIGHT. THE TERMINAL INVERSION CONJUGATES WITH THE NON-INVERTED END BY TURNING BACK, AS PROVEN BY THE SEQUENCE OF THE BANDS. (AFTER BRIDGES.)

the way in which the banded chromosomes confirm the genetic conclusions as to occasional changes that have taken place in the serial order of the genes. In Fig. 9 the right half of chromosome 3 from the salivary gland is represented. In part the two components are fused, in part are separate. In the lower part of the figure a reversed piece of one component is present (terminal inversion). Like bands conjugate with like and, as shown in the smaller diagram above, Fig. 9, this is made possible by the end of one component turning back on itself. In Fig. 10 is drawn a short region of chromosome 2. One component has a deficiency for certain genes; the opposite normal chromosome forms a bulge in the region of the deficiency, allowing like bands to come together above and below the deficiency level.

THE PHYSIOLOGICAL PROPERTIES OF THE GENES

If, as is generally implied in genetic work (although not often explicitly stated), all the genes are active all the time; and if the characters of the individual are determined by the genes, then why are not all the cells of the body exactly alike?

The same paradox appears when we turn to the development of the egg into an embryo. The egg appears to be an unspecialized cell, destined to undergo a prescribed and known series of changes leading to the differentiation of organs and tissues. At every division of the egg, the chromosomes split lengthwise into exactly equivalent halves. Every cell comes to contain the same kinds of genes. Why, then, is it that some cells become muscle cells, some nerve cells and others remain reproductive cells?

The answer to these questions seemed relatively simple at the end of the last century. The protoplasm of the egg is visibly different at different levels. The fate of the cells in each region is determined, it was said, by the differences in different protoplasmic regions of the egg.

Such a view is consistent with the idea

that the genes are all acting; the initial stages of development being the outcome of a reaction between the identical output of the genes and the different regions of the egg. This seemed to give a satisfactory *picture* of development, even if it did not give us a *scientific explanation* of the kind of reactions taking place.

But there is an alternative view that can not be ignored. It is conceivable that different batteries of genes come into action one after the other, as the embryo passes through its stages of development. This sequence might be assumed to be an automatic property of the chain of genes. Such an assumption would, without proof, beg the whole question of embryonic development, and could not be regarded as a satisfactory solution. But it might be that in different regions of the egg there is a reaction between the kind of protoplasm present in those regions and specific genes in the nuclei; certain genes being more affected in one region of the egg, other genes in other regions. Such a view might give also a purely formal hypothesis to account for the differentiation of the cells of the embryo. The initial steps would be given in the regional constitution of the egg.

The first responsive output of the genes would then be supposed to affect the protoplasm of the cells in which they lie. The changed protoplasm would now act reciprocally on the genes, bringing into activity additional or other batteries of genes. If true this would give a pleasing picture of the developmental process. A variation of this view would be to assume that the product of one set of genes is gradually in time overtaken and nullified or changed by the slower development of the output of other genes, as Goldschmidt, for example, has postulated for the sex-genes. In the last case the theory is dealing with the development of hybrid embryos whose sex-genes are assumed to have different rates of activity.

A third view may also be permissible. Instead of all the genes acting in the same way all the time or instead of certain kinds of genes coming successively into action, we might postulate that the kind of activity of all the genes is changed in response to the kind of protoplasm in which they lie. This interpretation may seem less forced than the others, and in better accord with the functional activity of the adult organ-systems.

We must wait until experiments can be devised that will help us to discriminate between these several possibilities. In fact, geneticists all over the world are to-day trying to find methods that will help to determine the relation of genes to embryonic and adult characters. The problem (or problems) is being approached both from a study of chemical

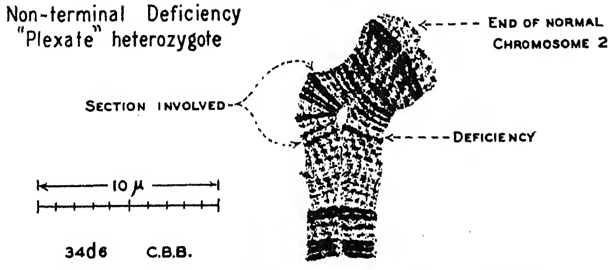


FIG. 10. SALIVARY GLAND PREPARATION SHOWING A PART OF CHROMOSOME 2. THERE IS A DEFICIENCY IN ONE OF THE TWO CONJUGANTS. AT THE LEVEL OF THE DEFICIENCY THE OTHER COMPONENT IS BENT OUTWARDS, SO THAT ABOVE AND BELOW THIS LEVEL LIKE BANDS MEET. THIS FIGURE ALSO SHOWS THAT THE SALIVARY CHROMOSOMES ARE MADE UP OF 16 STRANDS, THE 16 ELEMENTS OF WHICH FUSE TOGETHER TO MAKE EACH OF THE CROSS BANDS. (AFTER BRIDGES.)

changes that take place near the final steps in organ formation, especially in the development of pigments, and from a study of the early differentiation of the cell-groups of the embryo.

We have also come to realize that the problem of development is not as simple as I have so far assumed to be the case, for it depends, not only on independent cell differentiation of individual cells, but also on interactions between cells, both in the early stages of development and on the action of hormones on the adult organ systems. At the end of the last century, when experimental embryology greatly flourished, some of the most thoughtful students of embryology laid emphasis on the importance of the interaction of the parts on each other, in contrast to the theories of Roux and Weismann that attempted to explain development as a progressive series of events that are the outcome of self-differentiating processes or, as we would say to-day, by the sorting out of genes during the cleavage of the egg. At that time there was almost no experimental evidence as to the nature of the postulated interaction of the cells. The idea was a generalization rather than an experimentally determined conclusion, and, unfortunately, took a metaphysical turn.

To-day this has changed, and owing mainly to the extensive experiments of the Spemann school of Germany, and to the brilliant results of Hörstadius of Stockholm, we have positive evidence of the far-reaching importance of interactions between the cells of different regions of the developing egg. This implies that original differences are already present, either in the undivided egg or in the early formed cells of different regions. From the point of view under consideration results of this kind are of interest because they bring up once more, in a slightly different form, the problem as to whether the organizer acts first on the protoplasm of the neighboring region with which it comes in contact, and through the protoplasm of the cells on the genes; or whether the influence is more directly on the genes. In either case the problem under discussion remains exactly where it was before. The conception of an organizer has not as yet helped to solve the more fundamental relation between genes and differentiation, although it certainly marks an important step forward in our understanding of embryonic development.

Genetics and Medicine

That man inherits his characters in the same way as do other animals there can be no doubt. The medical literature contains hundreds of family pedigrees, in which certain characters, usually malformations, appear more frequently than in the general population. Most of these are structural defects; a few are physiological traits (such as haemophilia); others are psychopathic. Enough is already known to show that they follow genetic principles.

Man is a poor breeder—hence many of these family pedigrees are too meager to furnish good material for genetic analysis. When an attempt is made to combine pedigrees from different sources in order to insure sufficient data, the question of correct diagnosis sometimes presents serious difficulties, especially in the older materials; but with the very great advances that have been made in medical diagnosis in recent years this difficulty will certainly be less serious in the future.

The most important contribution to medicine that genetics has made is, in my opinion, intellectual. I do not mean to imply that the practical applications are unimportant, and I shall in a moment point out some of the more obvious connections, but the whole subject of human heredity in the past (and even at the present time in uninformed quarters) has been so vague and tainted by myths

and superstitions that a scientific understanding of the subject is an achievement of the first order. Owing to genetic knowledge medicine is to-day emancipated from the superstition of the inheritance of maternal impressions: it is free from the myth of the transmission of acquired characters, and in time the medical man will absorb the genetic meaning of the rôle of external environment in the coming to expression of genetic characters.

The importance of this relation will be seen when it is recalled that the germplasm or, as we say, the genic composition of man is a very complex mixture—much more so than that of most other animals, because in very recent times there has been a great amalgamation of many different races owing to the extensive migration of the human animal, and also because man's social institutions help to keep alive defective types of many kinds that would be eliminated in wild species through competition. Medicine has been, in fact, largely instrumental in devising means for the preservation of weak types of individuals, and in the near future medical men will, I suggest, often be asked for advice as to how to get rid of this increasing load of defectives. Possibly the doctor may then want to call in his genetic friends for consultation! The point I want to make clear is that the complexity of the genic composition of man makes it somewhat hazardous to apply only the simpler rules of Mendelian inheritance; for, the development of many inherited characters depends both on the presence of modifying factors and on the external environment for their expression.

I have already pointed out that the gene generally produces more than one visible effect on the individual, and that there may be also many invisible effects of the same gene. In cases where a condition of susceptibility to certain diseases is present, it may be that a careful scrutiny will detect some minor visible effects produced by the same gene. As yet our knowledge on this score is inadequate, but it is a promising field for further medical investigation. Even the phenomenon of linkage may some day be helpful in diagnosis. It is true there are known as yet in man no certain cases of linkage, but there can be little doubt that there will in time be discovered hundreds of linkages and some of these, we may anticipate, will tie together visible and invisible hereditary characteristics. I am aware, of course, of the ancient attempts to identify certain gross physical human types—the bilious, the lymphatic, the nervous and the sanguine dispositions and of more modern attempts to classify human beings into the cerebral, respiratory, digestive and muscular, or, more briefly, into asthenics and pycnics. Some of these types are supposed to be more susceptible to certain ailments or diseases than are other types, which in turn have their own constitutional characteristics. These well-intended efforts are, however, so far in advance of our genetic information that the geneticist may be excused if he refuses to discuss them seriously.

In medical practice the physician is often called upon for advice as to the suitability of certain marriages where a hereditary taint is present in the ancestry. He is often called upon to decide as to the risk of transmitting certain abnormalities that have appeared in the first-born child. Here genetics will, I think, be increasingly helpful in making known the risk incurred and in distinguishing between environmental and hereditary traits.

Again, a knowledge of the laws of transmission of hereditary characters may sometimes give information that may be helpful in the diagnosis of certain diseases in their incipient stages. If, for example, certain stigmata appear,

whose diagnosis is uncertain, an examination of the family pedigree of the individual may help materially in judging as to the probability of the diagnosis.

I need scarcely point out those legal questions concerning the paternity of an illegitimate child. In such cases a knowledge of the inheritance of blood groups, about which we now have very exact genetic information, may often furnish the needed information.

Geneticists can now produce, by suitable breeding, strains of populations of animals and plants that are free from certain hereditary defects; and they can also produce, by breeding, plant populations that are resistant or immune to certain diseases. In man it is not desirable, in practice, to attempt to do this, except in so far as here and there a hereditary defective may be discouraged from breeding. The same end is accomplished by the discovery and removal of the external causes of the disease (as in the case of yellow fever and malaria) rather than by attempting to breed an immune race. Also, in another way the same purpose is attained in producing immunity by inoculation and by various serum treatments. The claims of a few enthusiasts that the human race can be entirely purified or renovated, at this later date, by proper breeding, have I think been greatly exaggerated. Rather must we look to medical research to discover remedial measures to insure better health and more happiness for mankind.

While it is true, as I have said, some little amelioration can be brought about by discouraging or preventing from propagating well-recognized hereditary defects (as has been done for a long time by confinement of the insane), nevertheless it is, I think, through public hygiene and protective measures of various kinds that we can more successfully cope with some of the evils that human flesh is heir to. Medical science will here take the lead—but I hope that genetics can at times offer a helping hand.

ACCELERATED EROSION

ITS EFFECTS ON SOIL AND WATER RESOURCES

By Dr. W. C. LOWDERMILK

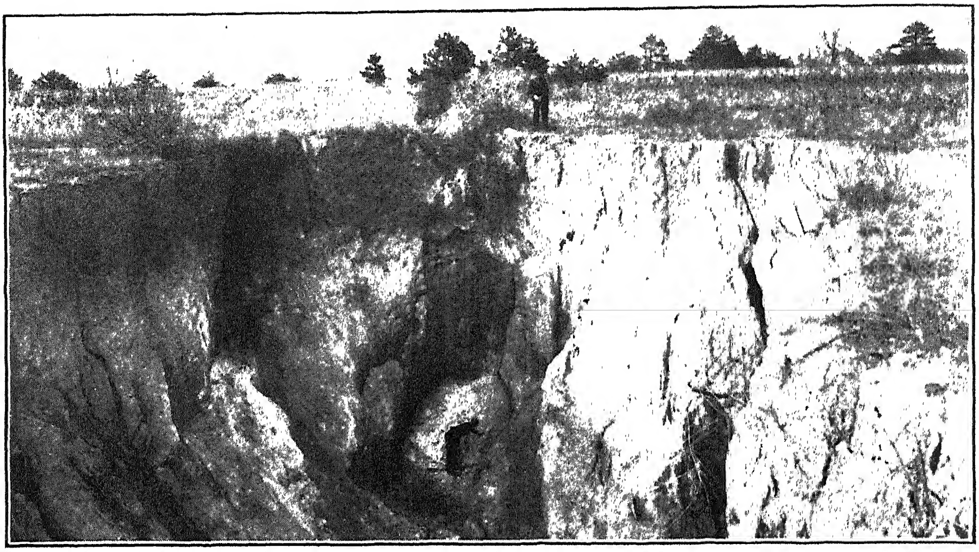
VICE-DIRECTOR, SOIL EROSION SERVICE, U. S. DEPARTMENT OF AGRICULTURE

IMMIGRANTS to the North American continent found a promised land fulfilling in its offerings the fondest imaginations of man. Neither to the sons of Abraham in Canaan nor to the sons of Han in Cathay were there offered such rewards for effort as the land of America held out to the eager explorers and colonists three centuries ago. It lay before their hopeful eyes rich in land, timber, game, fish and fur. So abundant were these good things that they were believed to be limitless and inexhaustible. This false concept has persisted in the thinking of the American people until to-day, long after limits in many areas have been reached. This concept has been responsible for a tardy realization of the need of wise use of natural resources for this generation and for those that follow.

Except in an insignificant way, the aborigines had done little to cultivate the soil or to change the pristine character of the land surface and its vegetation. The coverage of vegetation and the soils protected by it were responses to the long processes of soil and plant development under favorable climates. The streams bore oceanward the residue of precipitation that watered the land and nourished vast areas of vegetation. Rivers draining the regions covered with dense vegetation ran clear, except in high flood when channel erosion furnished the major burden of silt. This

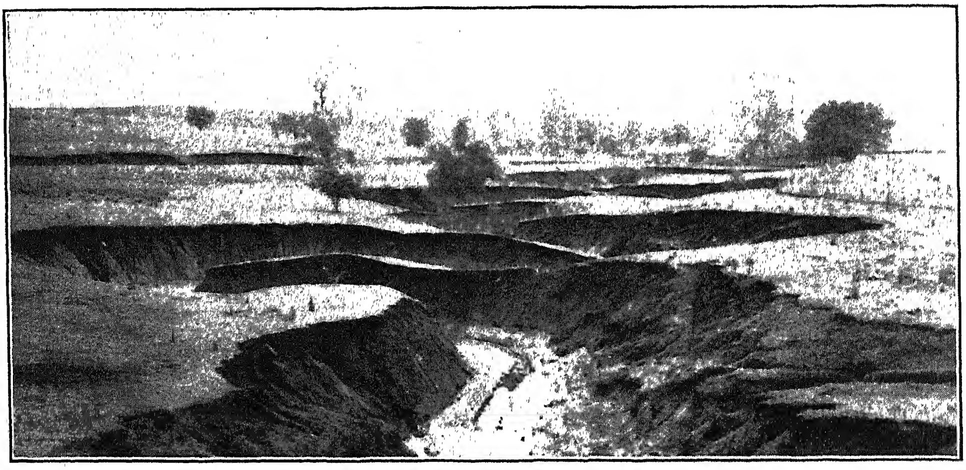
THE BREAKDOWN OF SOILS IN MISSISSIPPI

CAUSED BY UNWISE USE OF LAND. THE UTILITY OF THESE FORMERLY PRODUCTIVE LANDS HAS BEEN DESTROYED PERMANENTLY FOR FIELD CROPS, AND WITH IT THE FINANCIAL AND SOCIAL SECURITY OF EXTENSIVE RURAL SECTIONS. SOME DAY WE SHALL BE BADLY IN NEED OF THESE LANDS. PRODIGALITY OF THIS NATURE CAN NOT BE JUSTIFIED.



A GULLY IN THE PIEDMONT OF THE ATLANTIC SLOPE

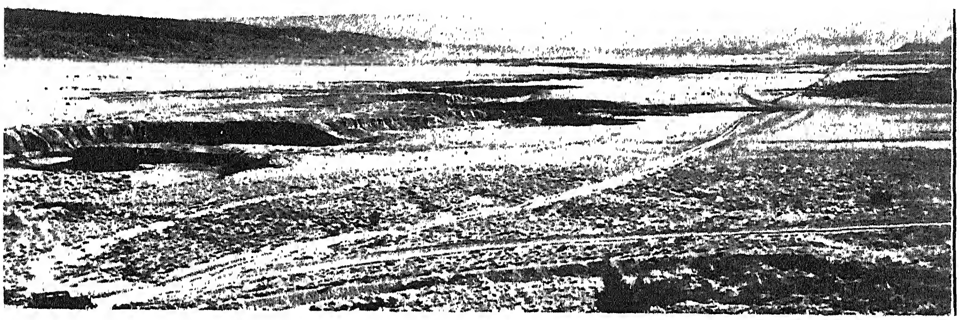
Tyger Creek Drainage, near Spartanburg, South Carolina. The original top-soil normally 12 to 16 inches deep in this region has been practically washed away by sheet erosion. Remnants may be seen on the edge of the gully. A heavy red clay sub-soil 3 to 5 feet deep overlies a deep highly weathered parent igneous material which crumbles and erodes rapidly once the tough sub-soil is cut through.



A MEANDERING GULLY

which has already ruined several acres of a fine bluegrass pasture, near Bethany, Mo., and is still cutting.

channel erosion generated soil creep from vegetated slopes and in addition to solution served to sculpture and wear down the land with the leisure of geologic processes. Where comparatively rapid differential land uplift had occurred or within climatic zones too rigorous or too arid to support an unbroken cover of vegetation, storm waters carried substantial quantities of silt into streams. Processes proceeded in these cases at more rapid rates; streams ran muddy throughout most of the year, as in the cases of the Missouri and Colorado.

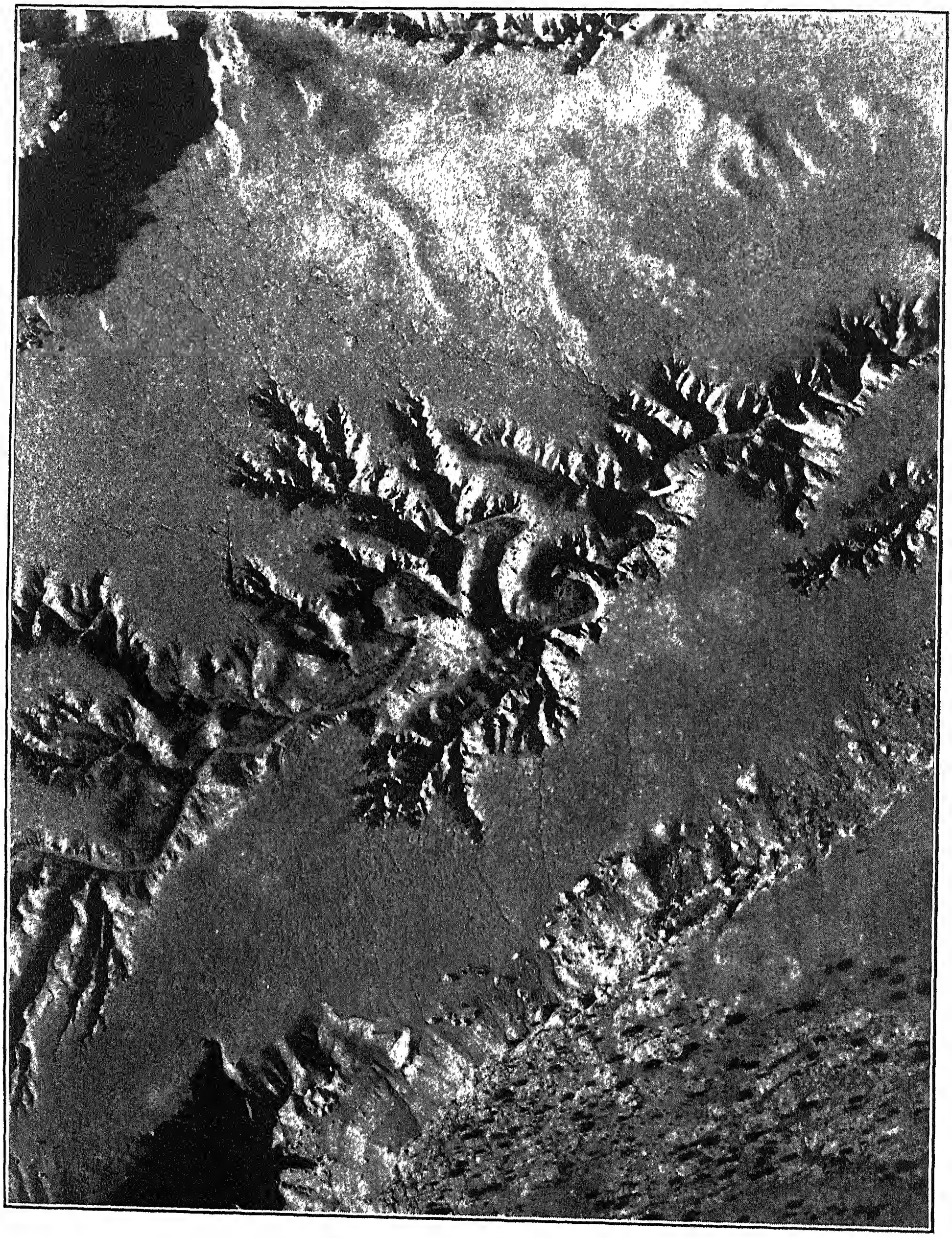


ARROYO EROSION IN NEW MEXICO

A VIEW OF A RAPIDLY ENLARGING GULLY ON ZUNI INDIAN RESERVATION SHOWING THE MANNER IN WHICH AN ALLUVIAL FILLED VALLEY IS BEING RE-EXCAVATED BY AN ARROYO. THE STAGE OF BASE LEVEL CUTTING HAS BEEN REACHED AND THE VALLEY FILL MATERIAL IS BEING EXCAVATED BY BANK CUTTING. MILLIONS OF ACRE FEET OF ALLUVIAL VALLEY MATERIAL IN WESTERN UPLAND VALLEYS IS THUS SUSCEPTIBLE TO EXCAVATION AND TRANSPORT INTO IRRIGATION RESERVOIRS. ACCELERATED CUTTING OF THESE ARROYOS MAY BE CHARGED TO THE CONCENTRATION OF RUNOFF INTO STREAMS OF HIGH VELOCITY, WHICH CUT LIKE RIP-SAWS INTO THE ALLUVIAL FILL. THE CONCENTRATION OF FLOW IS OCCASIONED BY BARING OF SLOPES BY OVERGRAZING, BY CATTLE TRAILS AND BY ROAD CONSTRUCTION WITHOUT DUE RESPECT TO THE SENSITIVE BALANCE BETWEEN DEPOSITION AND TRENCHING IN THIS REGION.

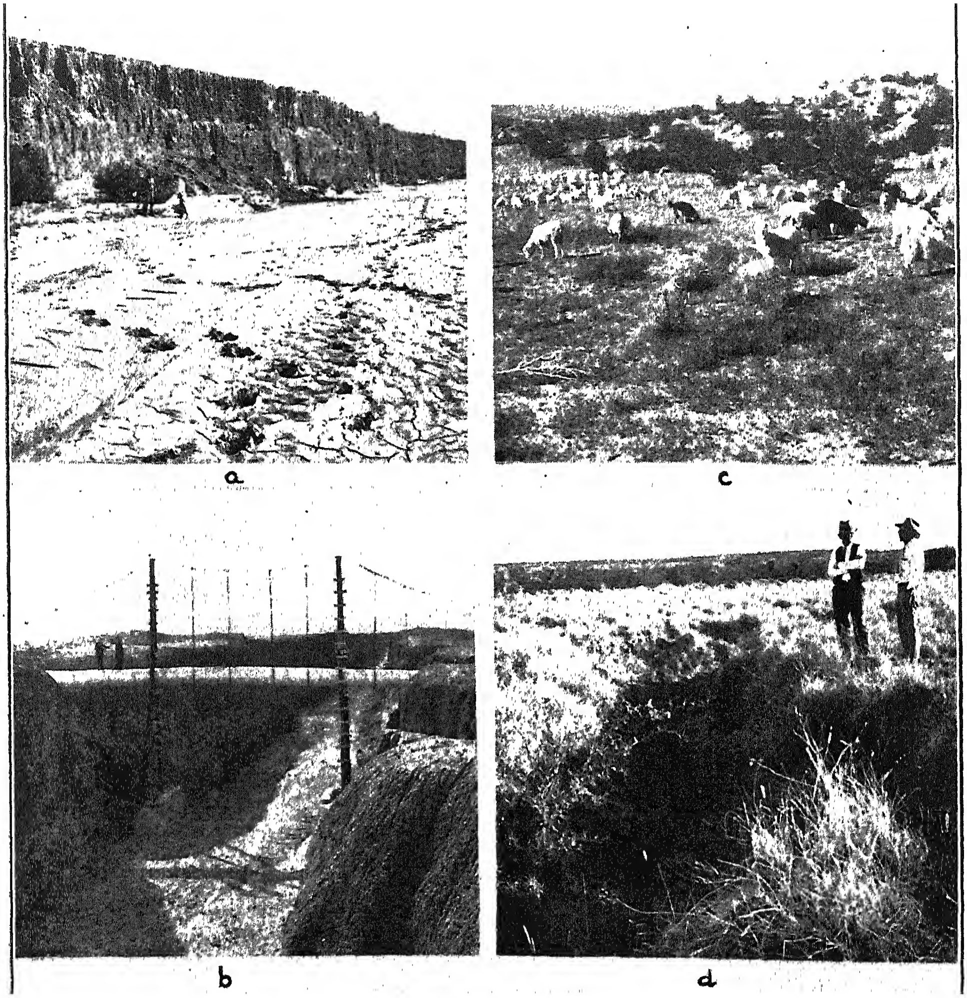
In the broad expanses of our country, from semi-tropical to boreal climates, from humid to arid conditions, there spread before the eager colonists an infinite variety of conditions. By far the larger area was completely covered by vegetation from grasses to dense forests. Such coverage had in the long period of interdependence of soil formation and vegetative succession protected surfaces of soils from rain wash, and favored the absorption of rain and melting snow by deep soils honeycombed by the burrowing of insects and plant roots. Little surface soil wash occurred. Certainly the processes of erosion, which may be designated under these circumstances as geologic norms of erosion, had not proceeded at rates in excess of those of soil formation: For beneath the coverage of vegetation lay the nourishing soils of varying depths, the product of intricate processes of soil formation during thousands of years. This fact is of highest importance in considering problems affecting the long-time planning in land use. Under native conditions erosion had not exceeded soil formation.

Into this pristine continent entered the eager colonists with a burst of energy that began a transformation of the earth's surface at a rate which probably had never before occurred in the earth's history, and with it the creation of a nation of fabulous wealth. There were reservoirs of population in Europe which supplied in a comparatively short time millions of vigorous people and their sons and daughters to clear away



AN OCTOPUS-LIKE GULLY

REACHING OUT WITH ITS TENTACLES TO DEVOUR THE VALLEY FILL OF ALLUVIUM IN ARIZONA, WHERE THE BALANCE BETWEEN DEPOSITION OF ALLUVIUM AND TRENCHING WITH GULLIES IS VERY SENSITIVE TO DISTURBANCES, SUCH AS OVERGRAZING. UNLESS SUCH CUTTING IS STOPPED THIS GULLY WILL REMOVE THE ALLUVIUM OF THIS VALLEY FILL AND MOVE IT DOWN THE DRAINAGE INTO IRRIGATION RESERVOIRS. THIS AREA IS HEAVILY OVERGRAZED BY SHEEP OF THE NAVAJO INDIANS.



EROSION IN THE SOUTHWEST

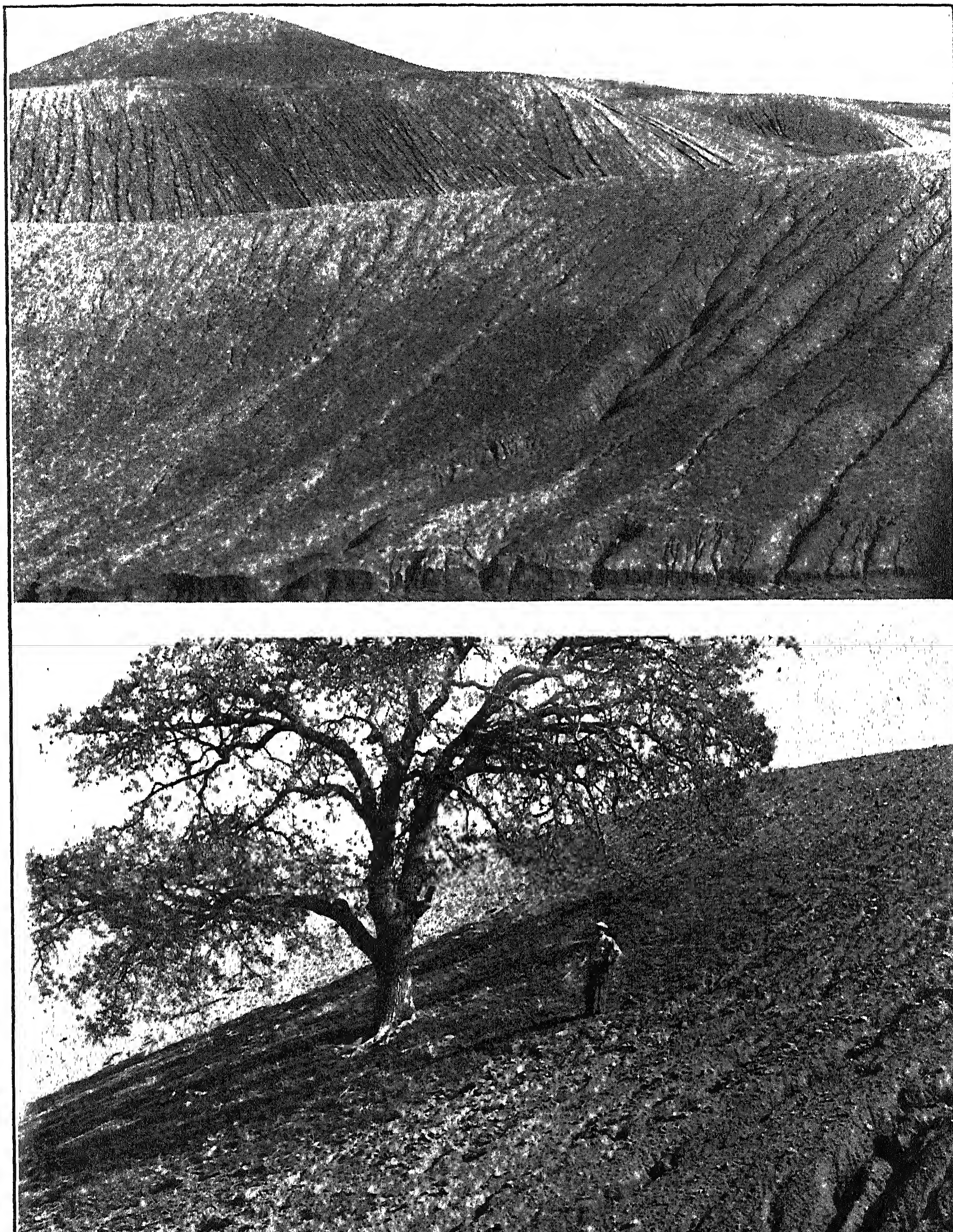
(a) The San Simon Wash. Some idea of the quantity of alluvium which has been washed out of this valley may be had when it is realized that in 1889 this valley had a flat floor level with the top of the bank. (b) Once the scene of a grassy flat which supplied hay and excellent grazing on the upper Gila River valley. The irrigation water now conducted in the suspended culvert flowed in an open ditch at this point 35 years ago. This great gully is cutting out rapidly and is feeding the San Carlos Reservoir with great quantities of silt to destroy storage capacity, in turn to jeopardize the irrigation project dependent upon it. (c) Sheep and goats may be useful and destructive, and in the end bring about conditions inducing quickened surficial runoff and accelerated erosion and gully trenching on western range lands. A herd on the Navajo country in Arizona. (d) A grassy flat, which represents the condition on alluvial valley floors in the Southwest when the white man came with his herds. Note that a gully has started as a result of accelerated run-off from surroundings.

the forests and to cultivate the soil at an astonishing rate in their westward march of agricultural occupation. It was no steady infiltration into undeveloped regions, but a rapid advance over a wide front by farmers and stockmen with their plows and herds. Frontiers were pushed farther and farther westward even to the Pacific shore by these sturdy folk with scarcely a thought for conservation or a planned use of these natural resources that lay before them to the horizon. It was the victorious occupation of an exultant invader. The advance was checked a little by the forests which required the hard work of felling and burning to clear the land. Advance was more rapid in the grasslands. The prairie sod was broken over vast areas, and next the short grass country of the great plains. Buffaloes were slaughtered by the thousands merely for their hides. There was no time to think of conservation, and waste marked the rapid occupation of the land. The habit of thought which the period of rapid occupation developed has persisted too long. The frontier has dissolved in the Pacific and reappears in the sustained and conservative use of the land now occupied.

Withal, it is only necessary here to call attention to the significant changes in rates of erosional processes occasioned by the clearing of vegetation and the breaking of the soil with the plow and the heavy consumption of the forage herbage by rapidly multiplying herds. Soils, which had been thoroughly protected through thousands of years of time by unbroken mantles of vegetation and had for this reason weathered to fine textures and high fertility, were suddenly exposed to the dash of torrential rains over extensive areas. There began under these conditions a rate of erosion which was accelerated far above the rate which had hitherto been obtained. The significant fact of this period of rapid agricultural occupation is that the rate of erosion exceeded and still does exceed the rate of soil formation over vast areas—a certain process of soil destruction. Top-soils have been literally washed away, leaving sub-soils exposed at the surface, such as is conspicuous over the entire Piedmont region of more than fifty million acres, as well as over numerous other regions of the country. Moreover, concentration of run-off has cut enormous gullies through top-soils and sub-soils into the underlying material often less stable than the soil above. So enormous has been the work of accelerated erosion as to reduce and destroy productivity of millions of acres of soils of densely populated regions of the United States within less than a century. The economic and social aspects of this transformation embody some of the most serious problems of the nation.

The acceleration of erosion in the east and in the south, in the north and in the west, has carried with it consequences of first importance in permanence of investments in the billions of dollars in navigation, hydroelectric power, municipal water supply and irrigation developments. Accelerated erosion has combined with an acceleration of superficial run-off from bared slopes to accentuate flood peaks and to augment the cutting power of stream flow. Still more significant is the transformation of fertile soils into troublesome silt and sediments. Products of soil wash and gully excavation have been carried by storm flows to be deposited in stream channels and in existing reservoirs. Shoaling of streams and rivers has followed large-scale erosion of upland soils. Particularly significant and important is the rapid rate of silting which is going on in reservoirs located on streams within critically eroding areas of the country. This applies to the East as well as to the West.

In the Piedmont region of the Atlantic Seaboard, many reservoirs impounded by dams constructed for the development of power have silted up to



WHAT HAPPENS WHEN A CLOUDBURST STRIKES AN OVERGRAZED AREA IN THE WEST—TCHACHAPI FLOOD OF 1932

ABOVE, FORMERLY GRASS-COVERED SLOPES RIDDLED WITH GULLIES IN A 7-INCH RAIN STORM. BELOW, A REMARKABLE EXAMPLE OF THE EFFECT OF A TREE AND ITS LITTER AND PROTECTED GRASS IN THE MIDST OF THE CLOUDBURST AREA. GULLIES WHICH STARTED ABOVE FANNED OUT ON THE GRASS AND LITTER COVER. AT NO POINT DID GULLIES CUT THROUGH THIS SURFACE.

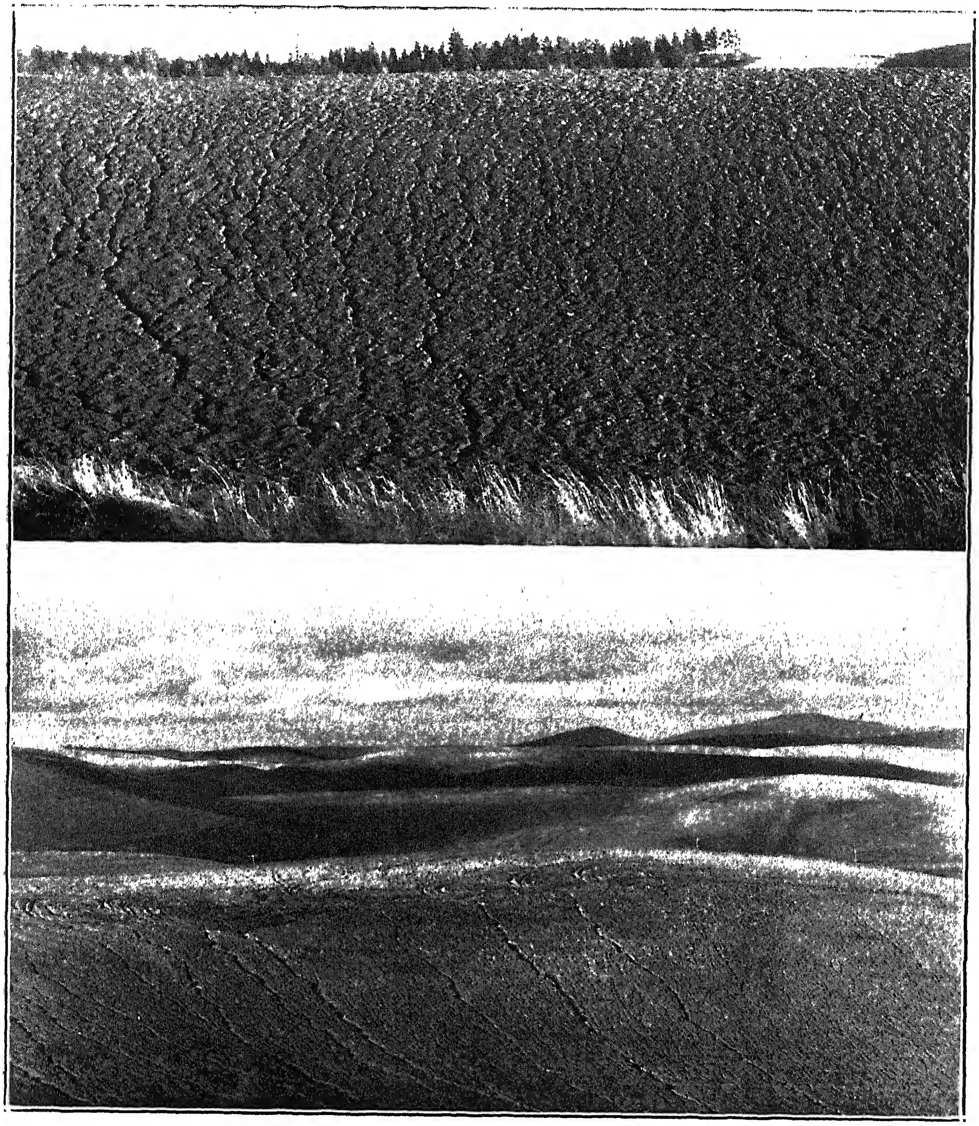
the very brim within the last 40 or 50 years. On the Deep River in North Carolina, 11 out of 13 such dams are reported to be entirely silted up. The reservoir at Oakdale near High Point, North Carolina, is now silted to the brim after 40 odd years and is a portentous example of the results of soil wastage on cultivated slopes within that drainage. On the other hand, the irrigated civilization of the West is doomed if the accelerated rate of silting in the irrigation reservoirs is not soon brought under adequate control. Hundreds of millions of dollars have gone into the construction of dams for power and for irrigation in the arid and semi-arid West. The Austin Dam in Texas has silted up to 85 per cent. of its capacity in 20 years. The Elephant Butte Reservoir of New Mexico with an original storage capacity of 2,638,860 acre feet supplies one of the largest irrigation projects of the West and is silting up at a disquieting rate. It was originally forecast to have a life of 233 years on the basis of silt studies of the Rio Grande River from 1897–1912, as reported by the *Reclamation Record*. After the completion of the Elephant Butte Dam in 1915, silt surveys have been regularly made in the reservoir. From 1915 to 1925 the average annual rate of silting was estimated at 20,000 acre feet, forecasting a life of 132 years; from 1926 to 1929, inclusive, 21,943 acre feet, forecasting a life of 110 years. Erosion of alluvial valleys above the reservoir is increasing yearly. But still more ominous is the fact that within approximately 60 years the storage capacity of this reservoir would equal the annual draft of water for the irrigated land. During dry years the lands will suffer a shortage of water, and from that time on irrigation under the Elephant Butte Reservoir will be a precarious enterprise.

These are samples of many other instances which ominously forecast financial losses, social insecurity and depopulation of regions dependent upon water stored in reservoirs. In the long view ahead, the situation is critical and calls for statesmanship in planning for coordinated uses of all the resources of water and land within these regions.

Conclusions that serious acceleration of erosion has taken place are not based upon field observation alone. They are founded upon experimental measurements at 12 erosion experiment stations, which have given quantitative values to the acceleration of erosion by processes of clearing for cultivation and by burning and overgrazing of native vegetation. Experimentally, the rate of superficial run-off from bared soils has been found to be from 3 to 40 times that from soils covered with unbroken vegetation and erosion many thousand fold that from slopes covered with vegetation. Measurements on the principal soil type of north-central Missouri within the drainage of the Missouri River have shown, for example, a loss of top-soil from corn land on an average slope of 8 per cent., equalling 67 tons per acre per annum, along with a superficial run-off of 26 per cent. of the total rainfall; whereas from the same type of soil thickly covered with alfalfa, the corresponding losses were 0.4 tons of soil per acre per annum, and with it 1.7 per cent. of the rainfall in run-off.

In approaching problems of coordinated use of waters, soils and vegetation on a long-time basis, the significance and implication of the acceleration of the processes of erosion must be taken into consideration and adequately met to safeguard and protect investments of billions of dollars and social security of millions of people.

The American people face two alternatives in this respect. One is to let continue the processes now destroying the productivity and utility of millions of acres of land and adding annually to a bankrupt domain which is becoming an increasing burden upon counties,



SHEET AND RILL EROSION IN THE PALOUSE REGION

Detail of the manner of work of sheet and rill erosion in removing top-soil from unprotected fields. This is suicidal agriculture; for the utility of crops of these lands under present practice is being destroyed. The Soil Erosion Service has developed practices of cultivation, and cropping and withdrawal from clean tilled crops which safeguards the utility of such lands to the present and future generations.

states and the Federal Government. Such a way out is not pleasant to contemplate. The other alternative is to diagnose the situation, take full account of the significance and trend of destructive processes of soil wastage, acceleration of run-off and sedimentation of reservoirs, to relate these to all land use within drainage basins and to set up a program to control and reduce these processes to a rate as far as possible and practicable equal to the rates which existed when the white man found the country covered with unbroken vegetation. Agriculture under such rates of erosion would cease to be self-destructive, and would be founded on a physical base for sustained production.

Production of agricultural field crops necessary for the provisioning of our people requires the clearing of land. Such clearing accelerates the rate of surface soil wash above the rate under a cover of native vegetation. The acceleration varies widely, however, with soil type, slope, nature and distribution of rainfall, and especially with methods of cropping and cultivating the soil. A division line between sustained cropping and suicidal agriculture exists in each region and should be drawn in the interests of the present as well as future generations. It is important to establish such a division line between practicable cultural and cropping methods. This is a task of first order of importance which the Soil Erosion Service is undertaking, on a series of 40 large-scale demonstration areas throughout the nation, located in representative regions of serious soil wastage through erosion.

To accomplish this herculean task requires drastic measures. Large areas of steeper slopes of erosive soils within rainfall zones of torrential downpour must be withdrawn from cultivation and returned to perennial crops of grass or forests. Partial redistribution of population of these sections is indicated. In other regions and districts, use of great areas of grass lands must be controlled and supplemented by artificial means of erosion control. Each drainage area is a problem unto itself and must be specially studied to work out measures applicable to the problems existing therein.

Summary

The beneficial use of waters of the nation can not be considered apart from the processes of erosion within the drainages yielding that water. Where human occupation and use may accelerate erosion so as to damage interests of navigation, hydro-electric power, municipal supply and irrigation development, special attention to coordinated use of these resources is required. Each region has peculiarities unto itself in the interrelations of rainfall, topography, natural vegetation and the soil which has been thousands of years in formation. There is needed principally a classification or zoning of each drainage, to assign to those zones the methods of culture or of production or utilization of its resources which would prevent the ruinous acceleration of erosion and of stream flow and the maintenance of the beneficial use of water resources. Within such a project may be forecast a program of development whereby not only will sustained productivity of soils be assured, but erratic flood flows will be minimized or reduced and beneficial power and utilization of the water of the country preserved in the highest degree.

NATURE IN SIAMESE AND CAMBODIAN ART

By Dr. GORDON ALEXANDER
ASSOCIATE PROFESSOR OF BIOLOGY, UNIVERSITY OF COLORADO

Art is of double inspiration. It is the expression of the inner man at the same time that it depicts the external world. It is preeminently the result of the interaction of man and nature. Thus nature and art are not identical and can not be identical; for art is derived not alone from its external inspiration, its objective source, but from the artist as well. It has a subjective element that can not be divorced from it. Although photographs made by different cameras may be alike, paintings made by different artists can not be.

In spite of the strong subjective element, however, it is obvious to artist as well as layman that much, probably most, of the art of a people consists of some kind of representation of natural objects, either topographic features, plants or animals, including, of course, man himself. Much conventional design has its origin in nature. Such a statement is perhaps less true of the art of an urban community, for there man's surroundings have been considerably modified by his own efforts, but in general, and especially in reference to countries with a traditional art of long standing, we may say that the art is derived chiefly from the natural environment.

Furthermore, and this assumption is generally made by archeologists, the most familiar objects occur with greatest frequency. Conversely, one assumes that if an object occurs frequently in the art of a primitive people that object was familiar to the people of whom the artist was a representative. Only recently, Dr. George Sarton[1] has made use of this assumption in suggesting that the existence of sexuality in the date palm was known, empirically at least, to the Assyrians of the ninth century B. C. Of course, where the art of a people may be studied with contemporary historical documents, this apparent assumption is thoroughly validated. Thus it is probably true that the most common subjects

[1] *Isis*, XXI: 8–13, 1934.

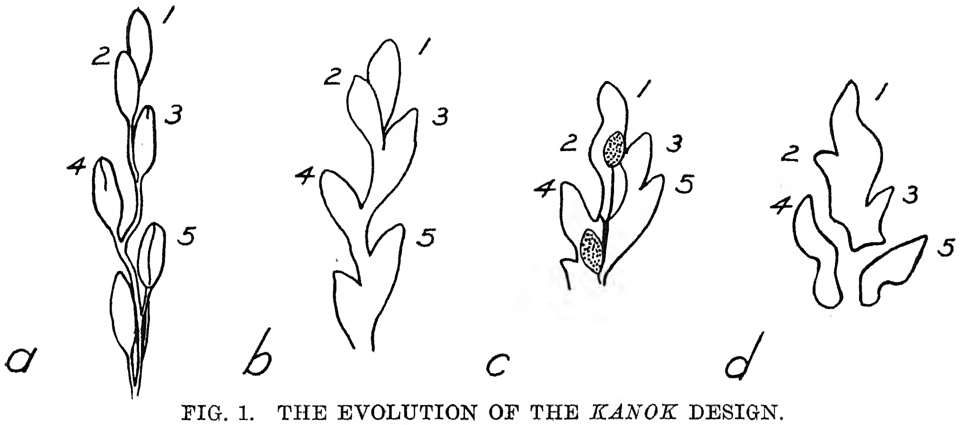


FIG. 1. THE EVOLUTION OF THE *KANOK* DESIGN.
THE FOUR FIGURES ABOVE REPRESENT THE POSSIBLE STEPS IN THE DEVELOPMENT OF THIS SIAMESE DESIGN FROM THE INFLORESCENCE OF THE RICE. a. A HEAD OF RICE. b. HYPOTHETICAL ANCESTRAL STAGE OF THE DESIGN. c AND d. CONTINUOUS AND BROKEN DESIGNS COPIED DIRECTLY FROM COMPARATIVELY RECENT AND RECENT ART OBJECTS, RESPECTIVELY.

FIG. 2. THE *KANOK* IN STONE IN BOLD RELIEF. SKETCHED FROM THE CRAYON (EIGHTH CENTURY A. D.) IN ANGKOR T'OM.

in a people's art are those things with which that people is most familiar.

As a corollary of the above, we assume further that the objects with which the artist is most familiar are represented most realistically. This does not mean, of course, that two artists, having equal familiarity with an object, depict that object with equal reality. However, it is in general true that familiar objects occur not only most frequently but are represented with the greatest fidelity to nature; although an object that has been conventionalized, and that has been used in art for many centuries, sometimes loses, in the form of representation, much of the appearance of its source.

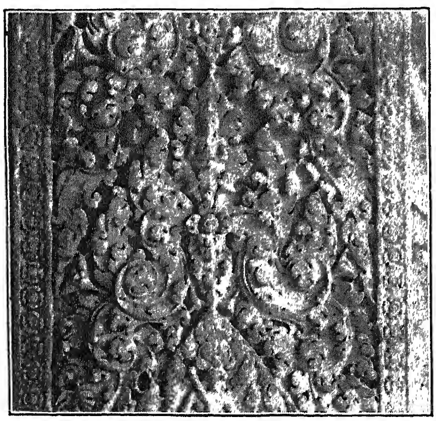


FIG. 3. CARVING IN ANGKOR WAT. THE *kanok* HERE OCCURS AS A COMMON MOTIF ON A LIMESTONE PILLAR.

FIG. 4. BOOK COVER DECORATIONS. PART OF THE DESIGN ON A MODERN SIAMESE BOOK-COVER. ENLARGED.

The most widely used design in Siam to-day, and perhaps for centuries past, is the *kanok* (also transliterated *ganok*, the initial sound being between the English *k* and *g*). The pattern is somewhat ornate and complicated, and appears, superficially, to have been derived from tongues of flame. In fact, certain types of the *kanok* pattern are said by Siamese students of their own art to have been taken from the flame. It seems generally recognized as a part of Siamese tradition, on the other hand, that the *kanok* is a rice pattern, that it was derived from the inflorescence of the

rice plant. It may have been modified in the direction of the flame pattern, and obviously has been in many special cases.

Actually, there is little to support this theory of the origin of the design except tradition, for the Siamese name *kanok*, which is derived from a Pali word meaning "end" or "termination," suggests nothing except part of the general form. Perhaps little is to be gained by theorizing as to the actual process of the metamorphosis of the rice inflorescence. If one assumes, however, that the tradition is correct, then one may feel free to imagine the steps in the process. Such the writer has done in Fig. 1.

To-day the kanok ornaments everything in Siam from silver coat buttons to temple doors. It is seen everywhere and is unquestionably the most characteristic design in Siamese art. In the past, its predecessor or counterpart was carved on the Borobudur, in Java, which

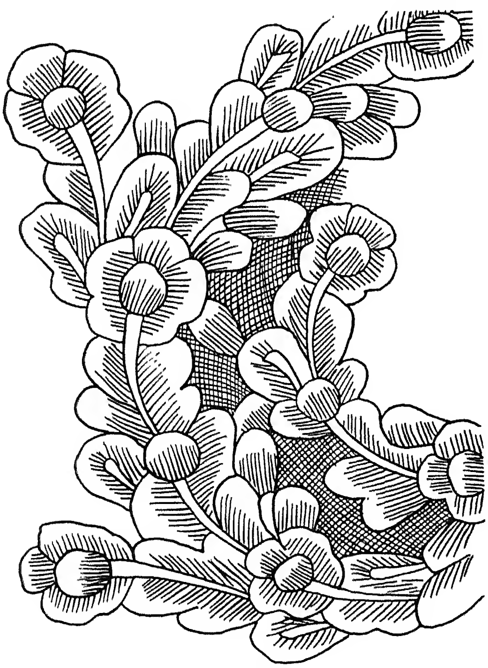


FIG. 5. PEACOCK-FEATHER DESIGN USED IN NORTHERN SIAM. NATURAL SIZE. THIS WAS COPIED FROM THE COVER OF A MODERN LACQUER BETEL-BOX. THE LINES IN THE ORIGINAL ARE WHITE ON A BLACK BACKGROUND.

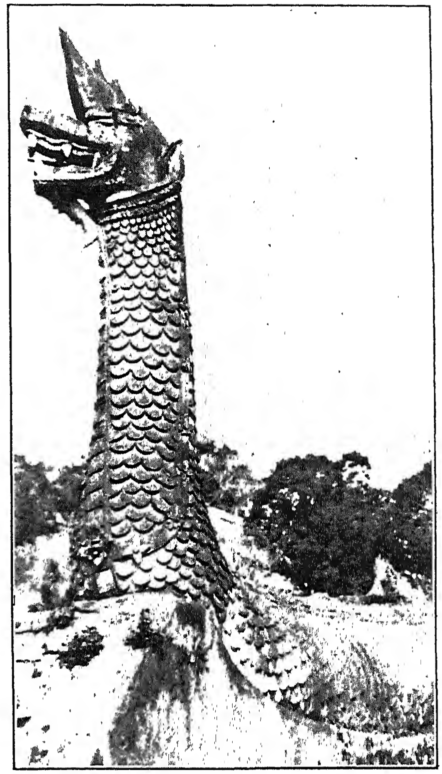


FIG. 6. A *NAGA* OF THE NORTHERN SIAMESE TYPE, AT NAN.

dates from the eighth century A. D. In Cambodia, the *kanok* appears, without question, on the Bayon (eighth century) in the ruined city of Angkor T'om. There it is carved boldly, in rather high relief (Fig. 2), and contributes the "rich floral design" of some descriptions. In Angkor Wat (completed in the twelfth century) it occurs as a common motif. The beautifully delicate carving on a stone pillar in this famous temple is reproduced in an accompanying photograph.

The Siamese probably acquired this design, as well as certain other characteristics of their art, in their more than two centuries of conflict and other commerce with Cambodia preceding the desertion of Angkor by the Cambodians in the 1430's. In time of origin the *kanok*

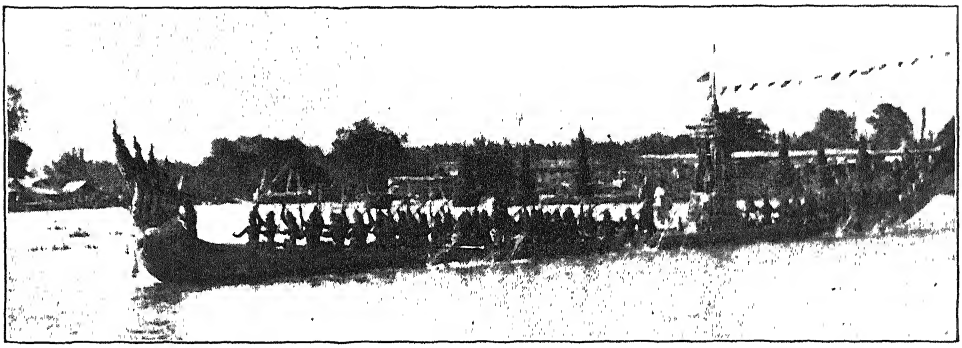


FIG. 7. ROYAL BARGE WITH NINE-HEADED *NAGA* AT THE BOW.

must, in any case, antedate the classical period of Cambodian art, for it had already become highly developed by the eighth century. But the rice plant has long been cultivated in southeastern Asia, and the ultimate source of the design may well have been this familiar plant—regardless of the time or place of origin.

Present-day modifications of the design have become, in many cases, exceedingly intricate. Figures of various

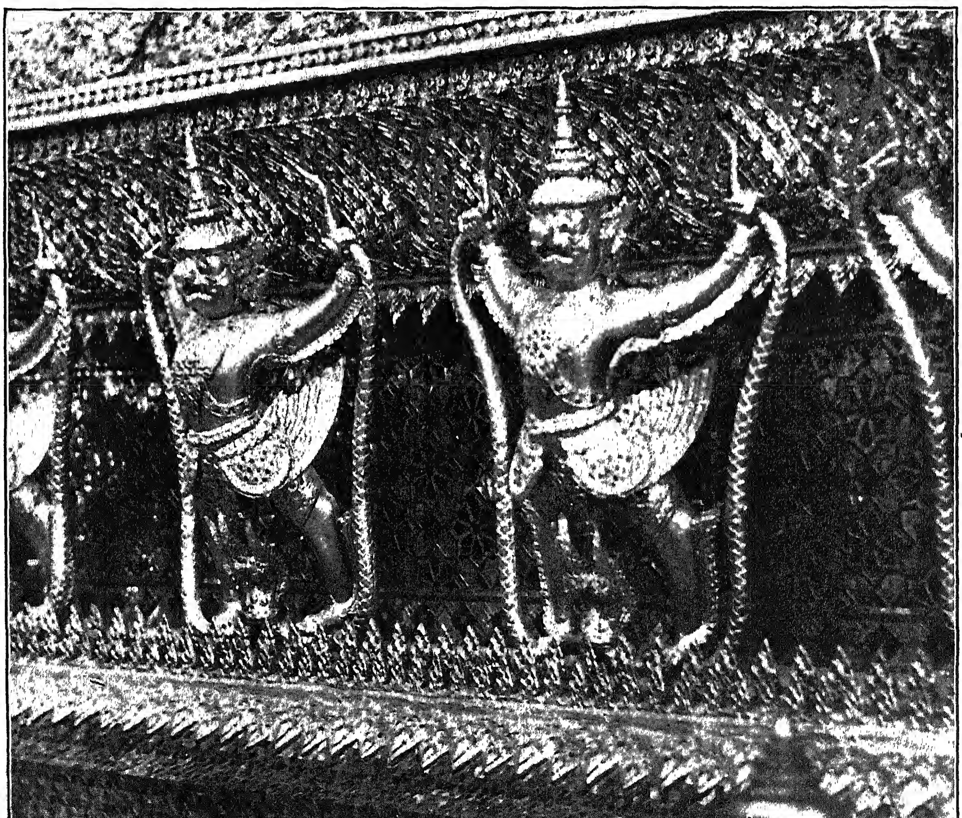


FIG. 8. *KRUTS* AROUND THE BASE OF WAT P'RA KEO, BANGKOK.

mythical creatures, in many different poses, form essential elements of the major design. In Fig. 4, a bit of detail from a modern decoration for a book cover serves to illustrate this well. The broken pattern (Fig. 1, d), illustrating the fourth stage in the development of the *kanok*, is taken directly from this design.

Two other conventional designs in common use are probably of natural origin. The *mali*-pattern is a modified floral design said to be derived from the leaves of the jasmine (*dok mali*, in

FIG. 9. *SING-TO*
A MYTHICAL LION, AND FRAGMENTS OF TWO *nagas* OF THE CAMBODIAN TYPE. ANGKOR.

Siamese). It has been a common decorative motif in central Siam. In northern Siam, a peacock-feather design is commonly used in the decoration of lacquerware (Fig. 5). This suggests an influence from Burma, rather than Cambodia, and illustrates the general principles that the art and architecture of northern Siam show closest affinity with those of Burma, whereas in central Siam the closest relationship is with Cambodia, to the east.

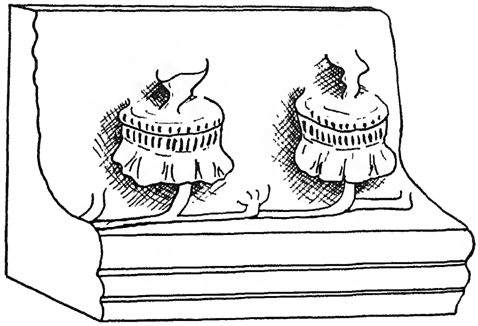


FIG. 10. LOTUS DESIGN
FROM THE BAYON, ANGKOR T'OM.

A host of monsters, which figure in the legends of southern Asia, decorate the temple grounds of Siam. To the visitor, the most interesting of these, and at the same time the most characteristic, are the *naga* (a serpent or dragon) and the *krut* or *garuda*, which is part man and part eagle. The first of these is, in the art of Cambodia[2] and Central Siam, unquestionably a hooded cobra, with, however, three, five, seven or even more

[2] H. Marchal, "Guide archéologique aux temples d'Angkor" (Paris, 1928). M. Marchal states explicitly that the *naga* is the conventionalization of the cobra. He also suggests that the *naga* and the *krut* are the most representative motifs in Khmer (Cambodian) sculpture and decoration.

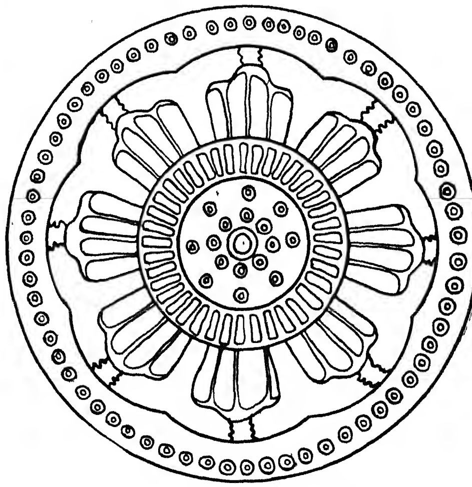


FIG. 11. A CONVENTIONALIZED
LOTUS DESIGN FROM UNDER SIDE OF STONE CEILING BEAM, ANGKOR WAT.

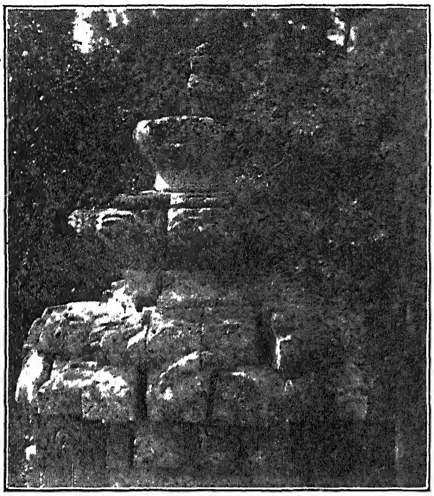


FIG. 12. A SMALL TOWER OF LOTUS DESIGN, IN ANGKOR T'OM. ABOUT TENTH CENTURY.

FIG. 13. A STONE ELEPHANT OF CAMBODIAN WORKMANSHIP, ABOUT 945 A. D. (PHOTOGRAPH BY MRS. FRANCES DAVIES.)

FIG. 14. WALL CARVING IN THE BAYON, ANGKOR T'OM. (PHOTOGRAPH BY MRS. FRANCES DAVIES.)

heads. In northern Siam, the creature which goes by the same name is not a cobra at all (Fig. 6). It is much more like the dragons of China, and is perhaps really a modified Chinese dragon with a Siamese name! There is at the P'ya T'ai Palace, Bangkok, a fountain in which the water flows from the mouth of a so-called *naga*, which is of the northern type, but with feet bearing claws. It is really a Chinese dragon in all but name.

I have occasionally heard people refer to the "plumed serpent" of Angkor. The *naga* is what is meant, but it should be noted that the resemblance between the *naga* and the serpent representation of the Mayas is extremely remote. There is no evidence in this figure-type for communication between the Old and New Worlds.

The *krut* or *garuda*, like the *naga*, has a wide occurrence in the art of southeastern Asia. It is a creature of great significance in the legends of India, where its rôle is that of the bearer of Vishnu through the sky. Its regal significance has been recognized in Siam, where it has been used as a symbol of officialdom. The *krut* is a bird-man hybrid. As also in the myths of the Hellenic world, numerous hybrid, mythical creatures occur in those of Further India and are consequently reproduced in its art.

A row of large, gilded *kruts* surrounds the base of the principal building of Wat P'ra Keo, the "Temple of the Emerald Buddha," in Bangkok. The accompanying Fig. 8 shows not only a few of these, but *nagas*, whose heads are held down by the feet of the *kruts*. The two are combined frequently in art. In several of the ruins at Angkor a *krut*, with arms outspread, rests, with body arched backward, on the seven hooded, upraised heads of the *naga*. This usually forms the lower end of a balustrade, of which the long, cylindrical body of the serpent forms the coping.

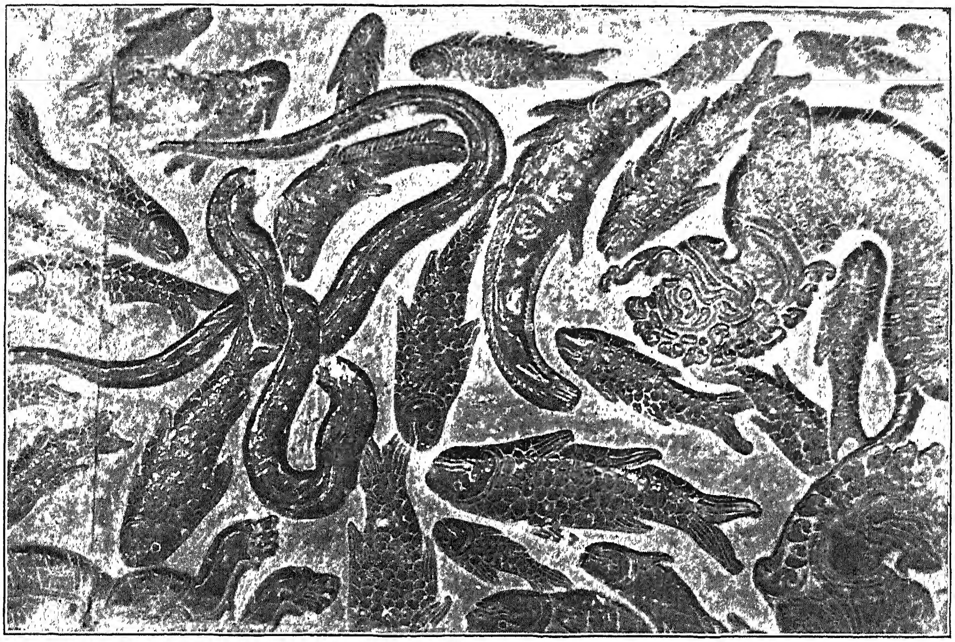


FIG. 15. WALL CARVING IN ANGKOR WAT.

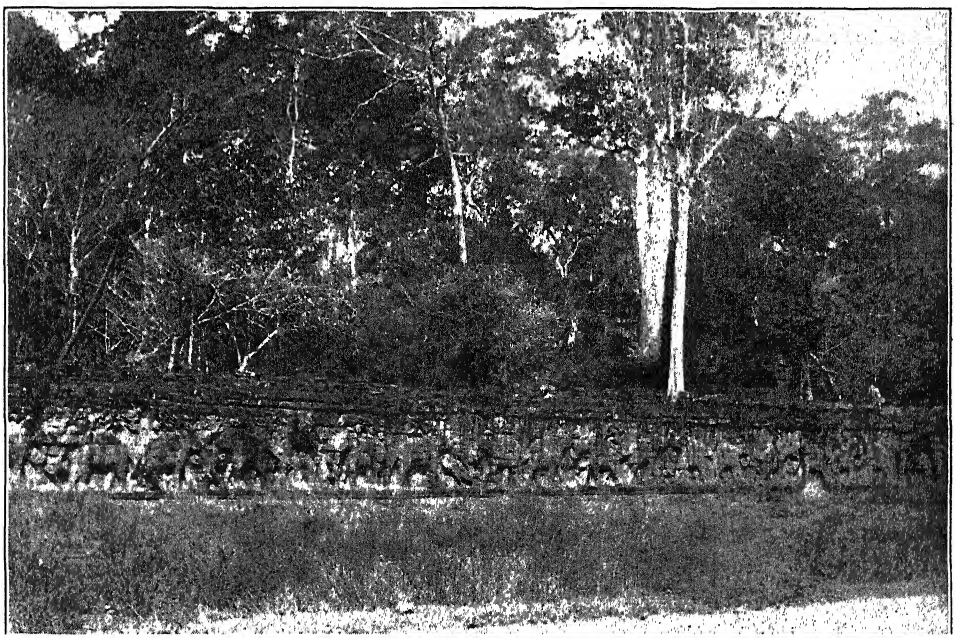


FIG. 16. A PORTION OF THE ELEPHANT TERRACE, ANGKOR T'OM.

More realistic representations are common enough, either as pictures pure and simple, or as a means of decoration. For the latter purpose, carved designs adapted from the lotus flower and seed receptacle occur frequently at Angkor. Some of the designs are very realistic; others have developed into a conventionalized, more or less geometrical, pattern. Sketches to illustrate the two types, as made by the writer at Angkor, are here reproduced in Figs. 10 and 11. The form of the lotus has probably contributed a great deal to the architecture of southern Asia. The accompanying photograph of a small tower in Angkor T'om, probably antedating the eleventh century, is of obvious lotus design. It is even possible that the *stupa* and the various forms of temple towers in Further India—either the tall spire (*chedi*) or the rather broadly-truncate tower (*prang*) of Cambodia—are of lotus origin.

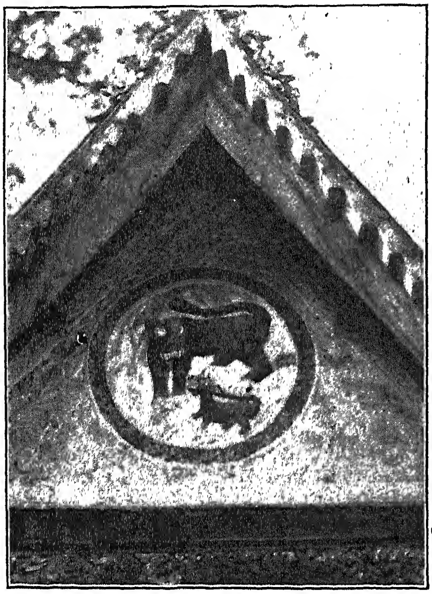


FIG. 17. TIGERS
PAINTED ON A TEMPLE EXTERIOR AT NAN, SIAM.

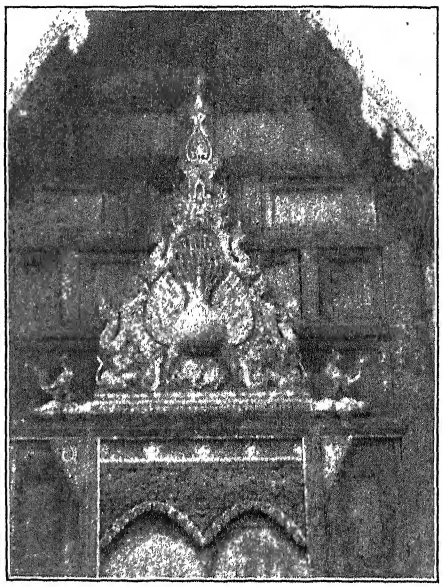


FIG. 18. A PEACOCK
IN PORCELAIN MOSAIC. THIS IS OVER A TEMPLE DOORWAY, CHIENGMAI, SIAM.

Pictorial representation of animals and plants occurs on an enormous scale in the bas-reliefs at Angkor, not only in the more extensive and recent ones of Angkor Wat, but also in the coarser work in earlier buildings, such as the Bayon in Angkor T'om. In the Bayon, although the work lacks the polish and refinement of the later artists, the subjects are executed with great skill, and, in faithfulness of representation, compare well indeed with that coming several centuries later (Figs. 14 and 15). There is nothing in modern Siam to compare with these, but there are large frescoes in several Bangkok temples, some of these paintings as recent as the present decade. It is worthy of note that no appreciable change can be observed in the more essential domestic processes since the time of the earliest reliefs in the Bayon, carved a thousand years ago. This statement is appropriate, of course, to the peasant class only. The Siamese farmer of to-day uses practically the same cooking utensils and tools that his predecessors did ten centuries ago; and

this in spite of the fact that he is familiar with guns, irrigation pumps and motor-cars!

As one might expect, the elephant is represented with considerable frequency. In Angkor T'om is the famous elephant terrace, a wall more than a thousand feet long and a dozen feet high, carved in relief to represent an elephant hunt in the forest. The elephants are nearly life-size. In the battle-scenes carved in the galleries of Angkor Wat elephants occur commonly. Also at Angkor, there are in full sculpture four large stone figures of elephants, one at each of the four corners of the building known as the Eastern Mebon. These were carved probably about 945 A. D. In the later, authentically historical, scenes in the frescoes of Bangkok temples elephants are represented in all the glory and gore of battle as well as in the panoply of royal ceremonials. The accuracy of the representations is remarkable. This is probably to be explained in the great familiarity of the artists with the object of their art, an animal which, until recently, was very extensively used in Siam.

Success in portraying the tiger, on the other hand, is, from my own observations, never very successful. The artist could never become as familiar with its form as with that of the elephant, in spite of the fact that he may frequently have seen dead individuals. Attempts at representation of the tiger are not numerous, and often seem to result in grotesques, as illustrated in the photograph (Fig. 17) from a temple at Nan, in a region in which tigers still occur and were formerly quite common.

Around Chiengmai, where the peacock-feather design is so extensively used in lacquer ware, pictorial representation of the peafowl, a bird of the northern jungles, occurs. A photograph of such is here reproduced (Fig. 18). In this case, it is a porcelain mosaic over the entrance to a temple. The frequent use of this bird in art may be associated either with its occurrence in this region or with the nearness to Burma, where its use in art, as in India, is quite common.

Only a most extensive study would bring to light all the uses of nature by the Siamese or Cambodian artist. This outline is merely a suggestion of the extent to which animals and plants determine the art motifs of this particular culture, and, indirectly, of any culture.

WHAT IS ELECTRICITY?[1]

By Dr. PAUL R. HEYL
NATIONAL BUREAU OF STANDARDS

I TRUST that there is no one in this audience so optimistic as to suppose that because I have asked this question I am going to answer it, nor so pessimistic as to fear that because I have asked a question which I can not answer I can offer you nothing but platitudes. I believe it possible in this case to avoid both Scylla and Charybdis.

This question, said the late Professor John Trowbridge,[2] of Harvard University, is often asked as though it were capable of a short and lucid answer which might be understood by any person of liberal education. Many answers have been given, but it is interesting to note that the more definite and confident the answer the older it is, and that as we ascend the ladder of time toward the present day such answers as we encounter are less definite and more cautious.

I think that it will be interesting for us to review, perhaps rather briefly, the ideas which have been held at various times as to the nature of electricity, and then, looking over the wealth of physical discovery which has been amassed in the past forty years, to endeavor to select from it such facts as may be of importance in guiding and controlling future speculation on this question; for though such speculation has been at a minimum, if not a standstill, during the twentieth century, it will doubtless revive again. Speculation or, as it has been otherwise termed, "apt conjecture, followed by careful verification," has been behind much of the advance of science. Such was the method of Faraday and of Darwin. The conjectures of the ancients, having little in the way of observed fact to guide them, might range far and wide, and had small heuristic value, but with the growth of experiment the range of conjecture has continually narrowed and its value as an aid to farther progress has steadily increased.

The beginning of our knowledge of electricity is lost in the mists of antiquity. What we can recover of it is excellently told by Park Benjamin in his history entitled, "The Intellectual Rise in Electricity."[3] It is customary to credit Thales (600 B.C.) with the first observation of the attractive power of rubbed amber, but Benjamin shows that amber was widely known among the ancients for centuries before Thales. Beads of amber have been found in the ancient lake dwellings of Europe, in the royal tombs at Mycenae (2000 B.C.) and throughout northern Italy. The identity in chemical composition of these relics with the amber of the Baltic sea coast is significant of the esteem in which this substance was held and of the distance over which it was thought worth while to bring it. The golden glow of the polished beads suggested the beaming sun, called by Homer ἠλέκτωρ, which doubtless gave rise to the Greek name for amber, ἤλεκτρον.

It is incredible, as Benjamin points out, that this wide-spread acquaintance of the ancients with amber should have existed so long without its electrical

[1] The fifth Joseph Henry Lecture presented on March 30, 1935, before the Philosophical Society of Washington in honor of its first president. Publication approved by the director of the National Bureau of Standards of the U. S. Department of Commerce.

[2] Trowbridge, "What is Electricity?" London: Kegan Paul, Trench, Trubner and Co., 1897.

[3] London, Longmans, Green and Company, 1895.

property being often noticed. It is probable that Thales but shared the knowledge of his time in this respect, for his acquaintance with the things of nature in general was such as to enable him to make the first recorded prediction of an eclipse of the sun. Thales left no writings of his own, and all we know of him we have learned from those who lived several centuries later.

It appears from these authorities that the ancients regarded electricity as a soul or spirit resident in an otherwise lifeless substance. This was in harmony with the prevailing thought of the times, which regarded all motion as evidence of life. The air was inanimate, but the wind was the breath of Aeolus; the waves of the sea were excited by the wrathful strokes of Neptune's trident; the lightning was the thunderbolt of Zeus. This animistic explanation of the nature of electricity was simple and definite enough to be understood by any one, and lasted for several millenniums; in fact, until the revival of learning and the growth of experimental science supplied material upon which to base a rival theory.

We are helped to realize this animistic point of view when we read in a translator's footnote to Gilbert's book on "The Magnet"[4] that a certain ancient physician recommended the administration of doses of powdered lodestone in cases of estrangement between husbands and wives. Given the premises of the time, such a conclusion was perfectly logical. It was obvious that the patients exhibited a deficiency of a certain spiritual element which was found in the lodestone, and the administration of that medicine followed as naturally as a modern prescription of cod liver oil because of its vitamin content.

It was the middle of the sixteenth century before the next answer on record was given to the question, "What is electricity?" This answer came from Cardan,[5] whose name is familiar to mathematicians (perhaps more so than it deserves to be). Cardan was the originator of the fluid theory of electricity which held the stage in one form or another for over three centuries, and survives to-day in popular parlance in the term "the electric fluid" or, still more colloquially, "the juice." Cardan passed from the spiritual to the material in his explanation, which was that amber "has a fatty and glutinous humor which, being emitted, the dry object desiring to absorb it is moved towards its source, like fire to its pasture; and since the amber is strongly rubbed, it draws the more because of its heat."[6]

In this last sentence we see the influence of Cardan's profession. He was, among other things, a physician, and was accustomed to warm the cupping glass in drawing blood from his patients. The laws of pneumatics were not yet understood at that time, and it was generally supposed that the cupping glass acted because of its heat.

The fact that this "fatty and glutinous humor" was intangible and invisible seems to have caused Cardan no embarrassment. We may perhaps view this the more charitably when we think of the contradictory attributes that later scientists have found it convenient to assign to the luminiferous ether.

The year 1551 in which Cardan published this theory may be taken as marking the end of the first era, in which electricity was regarded as a soul or spirit. Its beginning goes back beyond recorded history.

The concept of electricity as a material substance contained in certain bodies known as electrics was strengthened by the experiments of Gilbert

4 Translation by P. Fleury Mottelay, New York, John Wiley and Sons, 1893, page 56.

5 Cardan, *De Subtilitate*, Lib. XXI, Paris, 1551.

6 Park Benjamin, *op. cit.*, p. 248.

(1600), who showed that many substances besides amber were to be included in this class, but the full development of the fluid theory of electricity did not come until the middle of the eighteenth century. In the meantime, von Guericke (1672) had invented his sulphur globe electrical machine, which made electrical experimentation easy on a large scale. With the facilities thus placed at his disposal he discovered electrical conduction and electrostatic repulsion, the latter destined to be a phenomenon of prime importance in later speculation on the nature of electricity.

In the eighteenth century development of the fluid theory two names are prominent, those of Du Fay and Franklin, each typifying a separate trend in theory.

Du Fay's experiments (1733 and later) chronologically preceded those of Franklin. His most important discovery was that glass when rubbed behaved in one respect quite differently from amber; a bit of gold leaf excited by contact with the glass tube is then repelled by the glass but attracted by excited amber. "And this," said Du Fay, "leads me to conclude that there are perhaps two different electricities." These he distinguished accordingly as vitreous and resinous, and laid down the law that like electricities repel each other and unlike attract.

To explain the same phenomenon Franklin (1747) postulated a single electric fluid of which all bodies were normally full. If a body acquired more than this normal amount he called it "plus," or positively electrified, and if its charge was less than normal, "minus," or negatively electrified.

Franklin's hypothesis had simplicity in its favor; it required one less assumption than that of Du Fay. In this respect it obeyed more closely the rule laid down by Newton: "We are to admit no more causes of natural things, than such as are both true and sufficient to explain their appearances . . . for Nature is pleas'd with simplicity and affects not the pomp of superfluous causes.'"[7]

This simplicity of Franklin's hypothesis, added to the reputation which he himself rapidly attained in scientific circles, gave the one-fluid theory an advantage over its competitor for the time being, but a serious theoretical objection was soon raised against it. Since on this theory a negative charge meant a deficiency of electric fluid, there must be a limiting value of negative charge, namely, when the body is completely emptied of the electric fluid; but two such bodies, both being negatively charged, should repel each other—and why?

There was much hesitancy on the part of the one-fluid advocates about pushing this argument to its logical conclusion. It remained for a bold German named Aepinus (1759) to seize the bull by the horns and assert that matter devoid of electricity is self-repellent.

This doctrine came as a shock to a generation many of whom could remember Newton. It was useless to point out that Newton had deduced the law of gravitation by observation of bodies that possessed their normal amount of electricity, and that the behavior of matter with the maximum negative charge was something which no one had ever observed. The one-fluid theory had received a serious jolt from which it never recovered; this argument was used against it as late as the 1830's. The attention of theoretical physicists of the eighteenth century was turned toward the two-fluid theory, and during the closing years of that century and the early part of the nineteenth the work of Coulomb, Laplace, Biot and Poisson produced an elaborate and elegant mathematical theory which so well described

[7] Newton, "Principia," Book III: "Rules of Reasoning in Philosophy."

all the electrostatic phenomena then known that by 1830 the two-fluid theory was generally accepted.

But it often happens that as soon as one theory is comfortably settled on the throne another rises up to challenge its supremacy. We shall see the reign of each successive theory of electricity growing shorter. The thousands of years of the first era were followed by three centuries of the second. In the first half of the nineteenth century great things were happening. In 1820 Oersted had discovered that an electric current could produce a magnetic effect, thus tying together what had previously been regarded as separate phenomena. In 1822 Seebeck showed that electricity could be generated by heat. These discoveries impressed themselves on the mind of Faraday, then at work in the Royal Institution. He was familiar with the work of Davy in producing chemical decomposition by electricity, and the converse phenomenon of Volta, the production of electricity by chemical action. Faraday was also aware of the converse of Seebeck's discovery, the production of heat (and light) in the electric arc, and his thoughts turned naturally toward the undiscovered converse of the Oersted effect. He says himself at a later time[8] (1845):

> I have long held an opinion, almost amounting to conviction, in common I believe with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin; or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, into one another, and possess equivalents of power in their action. In modern times the proofs of their convertibility have been accumulated to a very considerable extent, and a commencement made of the determination of their equivalent forces.

Such were the considerations which led Faraday to attempt the generation of electricity by means of a magnet (1831). The story is familiar to all of us; how he placed a magnet in a helix of wire and found that no current was produced except momentarily while the magnet was being placed in or taken out of the coil. This discovery seems to have made quite an impression in other than scientific circles, as is evidenced by some verse which has come down to us:

> Around the magnet, Faraday
> Is sure that Volta's lightnings play.
> To bring them out was his desire.
> He took a lesson from the heart;
> 'Tis when we meet, 'tis when we part,
> Breaks forth the hid electric fire.

Encouraged by this success, Faraday later (1845) sought and found a correlation between magnetism and light. Twenty years later this in its turn furnished the inspiration for Maxwell's electromagnetic theory, by means of which the domain of optics was annexed to that of electricity.

The publication of Maxwell's paper in 1865 may be considered as closing the second era of electrical theory, that in which electricity was regarded as a material fluid, and the opening of the third era in which the concept of electricity assumed a less material and more elusive form.

By 1865 the two great doctrines of nineteenth century physics, the conservation of energy and the correlation of physical forces (as foreshadowed by Faraday) had been enunciated and were well on the way to general acceptance. During the seventies and early eighties electricity, in common with heat and light, was sometimes called, in the phrase of the day, "a mode of motion," which meant a form of energy.

The adoption of this view was, of course, a matter of slow growth. Maxwell's electromagnetic theory had a long struggle for acceptance, so long, in fact, that Maxwell himself did not live to see its final triumph. He died in 1879, and

8 Faraday, "Experimental Researches in Electricity," Vol. 3, p. 1, London, 1855.

it was not until 1886, when Hertz produced experimentally the electromagnetic waves which Maxwell's theory demanded, that its acceptance may be said to have become complete.

Against this concept of electricity as a "mode of motion," that is to say, a form of energy, Lodge[9] in 1889 entered a protest. He pointed out that water or air under pressure or in motion represents energy, but that we do not therefore deny them to be forms of matter. He emphasized an important distinction between two terms: *electrification,* which is truly a form of energy, as it can be created and destroyed by an act of work, and *electricity,* of which none is ever created or destroyed, it being simply moved and strained like matter. No one, said Lodge, ever exhibited a trace of positive electricity without there being somewhere in its immediate neighborhood an equal quantity of the negative variety.

Lodge did much to crystallize the ideas of the time concerning the nature of electricity. These ideas, since Maxwell's merger of optics with electricity, had been, as Lodge pointed out, not clearly defined, but in general the idea was that electricity was in some way a phenomenon of the ether. Lodge enlarged upon this idea, explaining electrostatic phenomena as due to ether stress, electric currents as ether flow and magnetism as ether vortices. Electricity, which had been previously regarded as a material fluid, now became an immaterial one, and in consequence this third period of electrical theory may be called the ethereal era.

As we mount toward the present time we see the different eras of electrical theory rapidly shortening in duration. While the spiritual era lasted several millenniums and the fluid theory three centuries, the ethereal era lasted only a few decades. The fourth era is that which is still with us. It may be called the atomic or quantum period, in which it is noteworthy that but little attention has been paid to the ultimate nature of elecricity and a great deal to its structure. It is difficult to say when this period began, as, in fact, the ethereal era began to die almost as soon as it began to live.

Wilhelm Weber,[10] in 1871, in developing his theory of magnetism, pictured to himself light positive charges rotating about heavy negative ones, much like a satellite about a planet; and in 1874 Johnstone Stoney read before Section A of the British Association a paper entitled, "The Physical Units of Nature," which was not printed until seven years later.[11] In this paper he asserted the atomic nature of electricity and made a rough calculation of the elementary charge on the basis of Faraday's law of electrolysis. Ten years later[12] he was the first to use the term "electron."

Helmholtz,[13] in his Faraday lecture at the Royal Institution in 1881, further developed this line of thought, saying (page 290):

> Now the most startling result of Faraday's law is perhaps this. If we accept the hypothesis that the elementary substances are composed of atoms, we cannot avoid concluding that electricity also, positive as well as negative, is divided into definite elementary portions, which behave like atoms of electricity.

Maxwell himself saw that his electromagnetic theory was essentially continuous in its nature and recognized the difficulty arising from the implications of Faraday's experiments. In his "Treatise on Electricity and Magnet-

[9] Lodge, "Modern Views of Electricity," p. 7, London, Macmillan and Company, 1889.

[10] Millikan, "The Electron," p. 20, University of Chicago Press, 2nd edition, 1924.

[11] Stoney, *Phil. Mag.*, 11: 381–390, 1881.

[12] Stoney, *Sci. Trans. Royal Dublin Society,* IV: 1891, 11th series, p. 563, 1891.

[13] Helmholtz, *Journal of the Chemical Society* (*London*), 39: 277–304, 1881.

ism'' (1873, Vol. 1, Chap. IV, page 313) in the chapter on electrolysis he says: ''It is extremely improbable that when we come to understand the true nature of electrolysis we shall retain in any form the theory of molecular charges.''

For Helmholtz, however, the atomic nature of electricity was beyond question. Electricity, as he saw it, was a special chemical element[14] whose atoms combine with those of other elements to form ions. Moreover, it appeared to be a monovalent element, for it seemed that a monovalent element combined with one electron, a bivalent one with two, and so on, exactly as a chlorine atom combines with one atom of hydrogen and an oxygen atom with two atoms of hydrogen. Helium, with its zero valence and double electrical charge, was as yet unknown.

The inevitable process of reconciliation of these contradictory theories was early begun by Lorentz,[15] who suggested for this purpose his electron theory of electricity. On this theory all the effects of electricity inside bodies were explained on the assumption of electrons, and all the effects of electricity at a distance, electrostatic, electromagnetic and inductive, required the help of the ether. To unite these two classes of phenomena he assumed that each electron was closely bound up with the ether, and that any change in configuration of the electrons produced a change in the ether which was propagated with the velocity of light, and thus produced action at a distance.

About this time an entirely new line of experimental research was developing which was destined eventually to make the atomic concept of electricity dominant for a time. This was the study of the electric discharge in high vacua. Several workers had investigated this field without attracting much notice, but it remained for Crookes to direct widespread attention to this class of phenomena by an exhibition of novel and beautiful effects in vacuum tubes which he gave at the meeting of the British Association at Sheffield in 1879. Crookes unquestioningly assumed these effects to be due to electrified molecules of residual gas in the tube. It was shown later by others (J. J. Thomson, Townsend, Wilson, Millikan) that the negatively charged particles in a Crookes tube were not molecules or even atoms, but bodies of a minuteness previously unknown, about the 1/1800th part of a hydrogen atom in mass, and bearing a definite negative charge of electricity. For these tiny bodies the term electron, introduced by Stoney, was revived. Still later work brought to light the proton, with an equivalent positive charge but larger mass than the electron and, in our own day, the positive electron.

As the result of this new line of investigation it became clear that a great many electrical phenomena required the atomic theory of electricity for their explanation. A great many, but not all; for a large number refused to fall in line under a corpuscular explanation, but could be simply and completely explained on Maxwell's theory as ether disturbances. The discovery by Hertz of the electromagnetic waves predicted by Maxwell did much to swing the pendulum back in this direction. The reconciliation of these contending views has been carried on much along the line originally taken by Lorentz. It is of interest to note that his idea of an electron inseparably bound up with the ether is found to-day in all essentials in the theory of wave mechanics.

We have now brought this somewhat hurried survey of electrical history up to the present day. We have seen that past speculations as to the nature of electric-

14 Graetz, ''Recent Developments in Atomic Theory,'' London, Methuen and Co., 1923.

15 Lorentz, *Verslagen en Mededeelingen der Koninklijke Akademie van Wetenschappen*, Amsterdam, 8: 323–327, 1891. Also *Archives Neérlandaises*, 25: Chap. IV, pp. 432 *et seq.*, 1892.

ity fall into four classes, each corresponding to an era of thought. In the first of these eras, beginning probably with the earliest observations of electrical attraction and terminating in the middle of the sixteenth century, electricity was regarded as a soul or spirit. The second era may be said to have been opened by Cardan in 1551 and closed by Maxwell in 1865. During these three centuries electricity was regarded as a material fluid of one or two kinds. It is worthy of note that during this period the concept of the electrical fluid showed a trend toward the immaterial, from Cardan's "fatty and glutinous humor" to the impalpable and imponderable fluid of the early nineteenth century. In the third era electricity in its various manifestations was regarded as some kind of an ether disturbance of a continuous nature. The fourth concept emphasized the atomic or discontinuous structure of electricity without any suggestion as to the ultimate nature of these atoms.

But though speculation as to the ultimate nature of electricity has been in abeyance since the opening of the twentieth century it will certainly arise again, and within limits it is well that it should. We may therefore turn now to an examination of the wealth of material which the last forty years have placed at our disposal and see what it may contain that is likely to be of importance in guiding and suggesting future speculation as to the nature of electricity.

The emphasis laid by the twentieth century on the structure rather than the nature of electricity is natural, for structure is much more easily determined than nature, and moreover a knowledge of the first is likely to give us some useful hints as to the second. It appears that the discontinuous structure of electricity goes almost hand in hand with that of matter. A tabular view of the known elementary particles of matter with their associated charges of electricity will be useful.

	Charge	+	−	0
Mass	Heavy	Proton	....	Neutron
	Light	+ Electron	− Electron	(Neutrino)

The heavy particles now known, the proton and the neutron, have a mass equal to that of a hydrogen atom; the light particles have about 1/1800 of this mass. The light neutral particle has not yet been discovered, but so urgent is the demand for it in current nuclear theory that it has been named before its advent.

According to the idea that has prevailed for two centuries, positive and negative electricity should be merely reflected images of each other, their properties being equal and opposite. The behavior of the negative electron and the proton shows nothing inconsistent with this concept as far as electrical properties go. On the discovery of the positive electron it was at first thought that it was shorter lived or, as a chemist might say, more reactive than its negative counterpart, but this has not been borne out by subsequent investigation.[16] The mass associated with the positive charge in this case has been investigated by several persons. The latest work is that of E. Rupp,[17] who finds that the mass is within 5 per cent. of that of the negative electron. Rupp appears to have found one point of difference between the two which, if confirmed, will be of importance.

It has been found that the passage of negative electrons through thin films of metal is accompanied by a diffraction effect, photographs of the electron beam after transmission showing a series of concentric rings. Rupp passed negative and positive electrons through the same films of gold and aluminum, and found

[16] Allowing for relative abundance.

[17] Rupp, *Phys. Zeit.*, 35: 999, 1934. But in *Zeit. für Physik*, 93, 278, 1935, Rupp has withdrawn his earlier article for revision.

that while the negative particles gave the usual rings the positive particles showed a continuous scattering. We will return to the interpretation of this later.

As to the neutron, it is still uncertain whether it is a proton which has acquired a negative electron or whether it is to be regarded as an independent entity without electric charge. The latter, as we shall see later, would be in serious conflict with present accepted electrical theory.

There was a time, not so very long ago, when the atom of matter was considered to be its ultimate structural unit. The discovery of the proton and the electron gave meaning to the term "sub-atomic." With this in mind, the question naturally arises as to a possible further subdivision of the electron. Several observers have claimed to have found evidence of smaller charges than that carried by the electron, but Millikan,[18] after an exhaustive discussion of the subject, came to the conclusion that up to 1924 there had been adduced no satisfactory evidence of this smaller charge.

In the early years of the present century there was some discussion as to whether the electron was to be regarded in shape as a rigid sphere (Abraham) or as contractile. The latter hypothesis was advanced by Lorentz to explain the negative result of the Michelson-Morley experiment. Lorentz supposed the electron, by motion through the ether, to flatten into an oblate spheroid. Experiments by Bucherer[19] in 1909 were interpreted as favoring the hypothesis of Lorentz.

But in 1927 a new line of experimental evidence as to the structure of the electron was opened up by Davisson and Germer,[20] soon followed by G. P. Thomson.[21] These investigators found, in brief, that electrons (of the negative variety) might be scattered by reflection or diffracted by passage through very thin films of metal in such a way as to suggest that an electron is at least as much like a little bunch of waves as it is like a particle, and that neither aspect can be ignored.

This is well brought out by G. P. Thomson's diffraction rings. The electron must have a wave aspect, or there would be no interference pattern; it must have a charged particle aspect, or the whole ring system would not be deflected by a magnet, as it is found to be. The whole situation, in fact, had been foreshadowed theoretically by the wave mechanics of de Broglie and Schrödinger.

A number of explanations have been offered for this dual behavior. Perhaps the most completely worked out is that of J. J. Thomson,[22] based upon the diffraction rings obtained by his son, which lend themselves particularly well to theoretical treatment. On this view the electron is associated with and accompanied by a group of waves which guide and direct its motion. Now it was found by a study of the speed of the electrons and the associated wave-lengths in the diffraction rings that a curious and complicated relation existed between these quantities. If u is the velocity of an electron and λ its associated wave-length, this relation is:

$$\frac{u\lambda}{\sqrt{1-u^2/c^2}} = C \qquad (1)$$

in which c is the velocity of light and C is a constant.

But this, as J. J. Thomson shows, is exactly the relation that should hold for the group speed of electromagnetic

18 "The Electron," Chap. VIII.

19 Bucherer, *Annalen der Physik*, 28: 513, 1909; 29: 1063, 1909.

20 Davisson and Germer, *Nature*, April 16, 1927; *Phys. Rev.*, 30: 705, December, 1927.

21 G. P. Thomson, *Proc. Roy. Soc.*, 117: 600, February 1, 1928.

22 J. J. Thomson, "Beyond the Electron," Cambridge University Press, 1928; *Phil. Mag.*, 6: 1254, December, 1928.

waves in a medium such as the Kennelly-Heaviside layer, containing a multitude of electric charges, positive and negative.

J. J. Thomson, therefore, suggests the following structure for the negative electron:

I. A nucleus which, like the older concept of the electron, is a charge of negative electricity concentrated in a small sphere.

II. This nucleus does not constitute the whole of the electron. Surrounding it there is a structure of much larger dimensions which may be called the sphere of the electron. This sphere contains an equal number of positive and negative charges, forming a little Kennelly-Heaviside layer around the nucleus. Measurements on the diffraction rings indicate a diameter for this sphere at least 10,000 times that previously accepted as the diameter of the electron.

III. The nucleus is the center of a group of waves and moves with the group speed in its atmosphere of electric charges.

At the time that J. J. Thomson proposed this hypothesis the positive electron was not known. Here comes in the importance of Rupp's work previously referred to (Reference 17). On their face, these experiments indicate either that the train of waves that accompanies a negative electron is absent from the positive electron or that all possible wave-lengths are present.

Just as the atom, once regarded as an ultimate structural unit, is now recognized as a complex of electrons, protons, neutrons and possibly neutrinos, so the electron, it seems, must be regarded as a similar complex. Much more, doubtless, is to be learned about its structure before we can hope to answer the question, "What is electricity?"

But perhaps the most outstanding fact in modern physical theory is the dominant position occupied by electricity. In the nineteenth century one spoke of matter and electricity as two separate and independent entities; nowadays electricity has become the fundamental entity of which matter is merely an aspect. Matter, once supreme, has lost its individuality and has become merely an electrical phenomenon of which electricity may exhibit more or less according to circumstances.

It is obvious that our answer to the question, "What is electricity?" will be fundamentally influenced according to whether we hold an electrical theory of matter or a material theory of electricity. It will therefore be worth our while to examine the foundation for the present view that electricity, whatever it may be, is the sole world-stuff. So radical has been this change in our thinking that it would seem a foregone conclusion that it must be based upon the clearest and most unequivocal of experimental evidence.

This change in our concepts did not come suddenly. Its beginning dates back to 1893, when J. J. Thomson[23] showed on theoretical grounds that a charged sphere in motion through the ether would encounter a resistance which to all intents and purposes would appear as an increase in the sphere's inertia, *i.e.*, in its mass. Calculation indicated that this effect would become appreciable only if the velocity of the charged body was comparable to that of light.

In 1893 this suggestion was of academic interest only, no bodies moving with sufficient speed being then available for experiment. A few years later conditions had changed. The study of radioactive substances and of the discharge of electricity through gases had placed at our disposal positively and negatively charged particles moving with unprecedented speeds, which in the case of the negative particles were in some cases comparable with the speed of light. Here, it would seem, was an opportunity to test Thomson's theory of increasing mass.

Unfortunately, the conditions of the problem were such that it was not at

[23] J. J. Thomson, "Recent Researches in Electricity and Magnetism," p. 21, Oxford, Clarendon Press, 1893.

first possible to obtain a measure of the mass of such a particle, but only a determination of the ratio of the electric charge to the mass which carried it (e/m).

Kaufmann[24] found, however, that for the swifter particles this ratio was less than for the slower ones. There were only two ways of explaining this fact, both equally radical: either the mass increased or the charge diminished as the speed of the particle became greater.

In this dilemma opinion inclined generally to the first alternative, largely because there was in existence a theoretical reason to expect it, while no one as yet had been ingenious enough to suggest any reason why a moving charge should alter. It is of importance to note that Kaufmann's experimental result, because of its equivocal character, can not be accepted as more than half proving J. J. Thomson's theory.

Kaufmann calculated that such particles as he experimented with might have, when moving slowly, an "electrical mass" equal to about one fourth their total mass. In making this calculation he assumed that a particle behaved as though it were a little metallic conductor, but he was careful to point out that a different assumption might lead to another result.

And so it happened. J. J. Thomson, on the assumption that a particle had no metallic conductivity, but acted like a point charge, found that Kaufmann's results indicated that the whole of the mass of the particle might be accounted for electrically.

This was the origin of the electrical theory of matter. Its pedigree goes back to J. J. Thomson's theory, which in turn was derived from the electromagnetic theory of Maxwell. Kaufmann's experiments only half proved Thomson's theory, which in addition was complicated by a special assumption with regard to the distribution of the charge on the particle. Without this assumption only a part of the mass could be accounted for electrically.

But much water has run under the bridge since 1893. Forty years is a long life for any physical theory in these days, and the recent discovery of the neutron has brought with it a challenge to the electrical theory of matter.

In J. J. Thomson's original theory of the increase in mass of a moving charge it was an essential point that the lines of force should be free to adjust themselves as the motion demanded. As a leaf or a card tends to flutter down through the air broadside on, so the lines of force, originally distributed radially and symmetrically about the charge at rest, will tend to set themselves in a plane perpendicular to the direction of motion of the charge. They will not all be able to lie in this plane because of their mutual repulsion, but the density of the lines will be a maximum in this plane and a minimum in the direction of motion, and a certain space distribution will result, of such a nature that the apparent increase of mass can be completely accounted for.

But it is essential for this result that the lines of force shall be perfectly free at their outer ends; in other words, only a single isolated charge is considered. Now in a structure like the hydrogen atom, composed of a negative and a positive particle, there is bound to be some interference with this freedom of adjustment. In a neutral, non-ionized atom it would appear that all the lines must begin and end within the atomic structure.

J. J. Thomson must be given credit for foreseeing this difficulty, though the Bohr atom was as yet years in the future. He had an atomic concept of his own in mind at that early date, and pointed out that the distance between the particles constituting an atom must be thousands

[24] Kaufmann, *Gesell. Wiss. Göttingen,* Nov. 8, 1901; July 26, 1902; March 7, 1903.

of times the diameter of a particle. In consequence, said he, almost all the mass will originate where the lines have their greatest density, near each particle; and the particles are relatively so far from each other that the parts of the lines of force in their immediate neighborhood will have almost perfect freedom of orientation with the motion of the atom.[25]

This is a quantitative question; but it is clear that only under the most favorable conditions will we have a freedom of motion in the atom which approximates that around an isolated charge, and in consequence the electrical explanation of matter, on J. J. Thomson's theory, must be in the same degree approximate.

With the neutron conditions are more rigid. Assuming the neutron to consist of a proton and a negative electron, the union of these must be almost as close as possible, as the neutron, on modern theory, may form a constituent of an atomic nucleus. Here we are dealing not with atomic magnitudes but with subatomic dimensions, which is quite another thing. Freedom of motion of the lines of force in such a structure must be almost non-existent. And if we make the alternative assumption that the neutron is an independent, non-electrical entity, the electrical theory of matter must admit of an important exception.

But an electrical theory of matter to be acceptable must admit of no exceptions. It must obey the all or none principle. If it is approximate in even the slightest degree, we are confronted with the existence of two kinds of matter, ordinary and electrical, and we are violating the rule of simplicity in reasoning laid down by Newton.

But has there not been later evidence supporting this theory?

It has sometimes been said that Millikan's oil-drop experiments, by which he measured the charge on a single electron, prove the constancy of this charge, and hence the variability of the mass alone in Kaufmann's experiments. It is true that Millikan found that the charge on an ion *after it had been transferred to the oil-drop* was the same whatever the source of the original charge. Ions of different gases, unquestionably of different speeds, gave the same charge to the drop. But it is to be remembered that the measurement of this charge was made, not at the speed of the ion, but at that of the oil-drop, which was of the order of a few hundredths of a centimeter per second.

The special theory of relativity is sometimes quoted in support of the constant charge and variable mass. It is true that Einstein[26] in his original paper of 1905 gives a formula for the change of mass with the speed of a moving electron, which, like J. J. Thomson's formula, becomes infinite at the speed of light, and that he gives no similar formula for a change in the charge. It will be interesting for us to see how he obtained this result.

In section 10 of his paper Einstein derives the following formula for the x-component acceleration of a moving charged particle, together with formulas for the other components:

$$\frac{d^2x}{dt^2} = \frac{e}{m}\frac{1}{\beta^3}X$$

in which e is the charge on the particle, m its rest mass, X the component of the electric vector and β the familiar $1/\sqrt{1-v^2/c^2}$.

It is evident that the quantity e/m is altered by the factor $1/\beta^3$, but whether the charge or the mass or both are changed is not obvious. Einstein without comment assumes e to be constant and m to bear the full effect of the modifying factor, and on this basis derives his formula for the change of mass.

[25] J. J. Thomson, "Electricity and Matter," New York: Scribner's, p. 51, 1904.

[26] Einstein, *Annalen der Physik*, 17: 891, 1905.

This assumption, of course, was orthodox in 1905, but it is of interest to note that as a matter of logic the electrical theory of matter can claim no supporting evidence from the special theory of relativity.

On the basis of this result of Einstein's, Sommerfeld[27] introduced a modification into Bohr's theory of the atom. On Bohr's theory the hydrogen atom was regarded as consisting of a negative electron revolving in a Keplerian ellipse around a positively charged nucleus, the attraction between the two charges being balanced by the centrifugal force of the revolving electron. Sommerfeld (page 45) makes the orthodox assumption that the electrical charges remain constant, but that the mass of the revolving electron varies with its speed according to Einstein's formula. In consequence the mass of the electron fluctuates as it describes its orbit, being greatest at perihelion and least at aphelion, and its centrifugal force will vary slightly from that in a non-relativistic Keplerian ellipse. Because of this the orbit becomes an ellipse with a moving perihelion, like that of the planet Mercury. The effect of this will be to split up the spectral lines, producing what Sommerfeld called the relativistic fine structure.

This predicted effect has actually been found in the spectra of hydrogen and helium, the number of the component lines and their relative separation being in accordance with theory.

As to the value of this result as a confirmation of the electrical theory of matter, it is to be observed that Sommerfeld would have obtained exactly the same modification of the Keplerian ellipse if he had assumed the charge to decrease and the mass to remain constant, thereby disturbing the balance by reducing the centripetal attraction instead of increasing the centrifugal force.

[27] Sommerfeld, *Annalen der Physik*, 51: 1, 1916.

The logic of the whole situation is that the electrical theory of matter can claim no independent support from Millikan, Einstein or Sommerfeld. It rests for the present on J. J. Thomson's theory, and even this theory assumes tacitly that the charge is unaltered by the motion. It is remarkable that every one we have mentioned, from J. J. Thomson onward, when confronted with the necessity of making a choice, prefers to keep the charge constant and let the mass take the consequences, and this without comment or apology.

Of course, there must be a reason for this; and although it is explicitly stated by no writer that I have seen, the reason is doubtless to be found in a fundamental law of electricity, that of the conservation of electrical charge, with its corollary, the exact equivalence of positive and negative electricity. This law states that no one has ever produced the slightest trace of a positive charge without the simultaneous production of an equal and opposite negative charge somewhere in the neighborhood.

This law has been the subject of some very searching experiments. We may operate within a large conducting cube, such as was built by Faraday at the Royal Institution; perform within it all the usual electrical experiments, excite a glass tube by rubbing it with fur, draw sparks from an electrical machine, and yet a sensitive gold leaf electroscope connected to the cube will remain undisturbed. It seems impossible to create or destroy an electric charge without a compensating creation or destruction of an equivalent charge of the opposite sign.

And yet the era of thought which has not hesitated to question the conservation of energy can hardly be expected to respect this electrical principle; and in fact this law has been brought under fire from several quarters. If these points of order are sustained they will have an important bearing on future answers to the question "What is electricity?"

It is well to remember in this connection that all the experiments upon which is based the law of conservation of electric charge have started with neutral bodies. The glass tube and the fur were at first neutral, but exhibited equal and opposite charges after being rubbed together; the electrical machine was at first neutral, but on being operated its two sides became equally and oppositely charged.

Suppose a chemist should announce that as a result of the analysis of several thousand neutral salts he had come to the conclusion that acid and basic radicals existed in equal amounts in nature; we would likely think him ignorant of such syntheses as that of the acid radical cyanogen (CN) from its elements in the electric arc.

But is there any known electrical analogue of such a synthesis or its reverse dissociation?

No, nothing that we have so far been able to produce in the laboratory; yet if we imagine some race of children of the gods who could play with planets as we with pith balls, something of this kind might come to their notice.

Among the phenomena of atmospheric electricity there is an unsolved mystery. Many fruitless attempts have been made to explain it consistently with the principle of conservation of electrical charge. Continual failure has led more than one physicist to look for the explanation in a slight departure from this principle, and it has been shown that a departure so slight as to be beyond laboratory detection would yet, on the large scale, solve this mystery. The difficulty in question is to account for the negative charge of the earth.

For our earth is not a neutral body. Its entire surface is negatively charged to such an amount that there exists near the surface a potential gradient of 150 volts per meter. The conductivity of the atmosphere is small, but not zero; and because of this conductivity and the potential gradient there is a continual conduction of negative electricity away from the earth amounting, over the whole surface of the earth, to a current of about 1,000 amperes. Small as this may appear, it is sufficient to bring about a loss of 90 per cent. of the earth's charge in ten minutes if there were no means of replenishing the loss. The nature of this replenishment is the mystery referred to.

So great has been the difficulty of accounting for this replenishment that in 1916 G. C. Simpson,[28] now director of the British Meteorological Office, raised the question of a possible spontaneous production of a negative charge in the earth's interior, but offered no suggestion as to how this could be brought into line with existing theory.

In 1926 Swann,[29] who had worked unsuccessfully with the same problem, followed Simpson's lead, but chose the other alternative of a slight annihilation, or as he called it, death of positive electricity. He was able to bring this into connection with existing electrical theory by generalizing Maxwell's equations. His fundamental idea was that there might be a very slight difference in the properties and behavior of the two electricities. Here again we are reminded of the difference apparently found by Rupp.

Such a suggestion was not without precedent. Lorentz[30] in 1900 had postulated a difference between the attraction of unlike charges and the repulsion of like charges to account for another mystery—gravitation. It must be admitted that the accepted idea of the absolute equivalence and mirror-image

[28] G. C. Simpson, *Monthly Weather Review*, 44: 121, 1916.

[29] Swann, *Journal Franklin Institute*, 201: 143, 1926; *Phil. Mag.*, 3: 1088, 1927.

[30] Lorentz, Koninklijke Akademie van Wetenschappen te Amsterdam, *Proceedings of the Section of Sciences*, 2: 559, 1900.

character of the two electricities had weakened somewhat when such men as the director of the British Meteorological Office, the director of the Bartol Research Foundation and a Nobel prizeman could join in expressing doubt of its accuracy.[31]

Swann's theory of the maintenance of the earth's charge is, from the theoretical point of view, the most successful that has yet been advanced. He modifies the equations of Maxwell by introducing two small terms, amounting respectively to one part in 10^{26} and five parts in 10^{19} of the main term of the classical theory. These additional terms involve the acceleration and time rate of change of positive charge.

Swann assumed no similar terms for the negative charge, his idea being that there is a slight differential effect in behavior. For simplicity, therefore, he introduced a differential term applying only to positive electricity. This assumption enabled him to account for a slow death of positive electricity due to the centripetal acceleration produced by the earth's rotation.

To account for the known electrical facts, there is necessary an annihilation of less than one proton per cc per day, equivalent to a loss of 0.5 per cent. of the earth's mass in 10^{20} years. This would also account for as much of the earth's magnetic field as is symmetrical about the earth's axis, and would give the correct ratio for the magnetic fields of the earth and the sun. Moreover, no development of charge or magnetic field could be detected with a sphere of laboratory size rotating at the highest practicable speed. And finally, Swann's scheme is consistent with the special theory of relativity.

Whatever may be thought of Swann's fundamental assumption, it must be admitted that his theory is experiment-proof. Moreover, even though it should be definitely disproved, it would have the lasting merit of impressing upon us caution in extrapolating laboratory results to the cosmic scale.

The relations of newly discovered fact and existing theory are, as we have seen in this somewhat brief survey, rich in suggestion. Speculation is not dead, but sleeping. If the past is still an indication of the future, it will awake again to renewed activity, and when this occurs we will need a wide acquaintance with fact and a good sense of perspective to guide and direct future speculation on the question, "What is electricity?"

[31] Additional references: More, *Phil. Mag.*, 21: 196, 1911; Gleich, *Annalen der Physik*, 83: 247, 1927; W. Anderson, *ibid.*, 85: 404, 1928; A. Press, *Phil. Mag.*, 14: 758, November, 1932.

THE PROBLEM OF FARM TENANCY

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During the past half century, the increase of farm tenancy has been one of the undesirable and yet wide-spread characteristics of rural America. Only two generations ago we were at the heights of the homestead movement, which had as one of its fundamental aims the creation of an agriculture made up predominantly of small farm operators. To-day we find that half of our farm lands are operated by tenants, and nearly that large a percentage of our farmers rent all the land they farm.

By the homestead laws and legislation of earlier years, the development of family-sized farms owned by resident farm operators was encouraged and promoted. This was a wise and highly desirable feature of our land policy. Unfortunately, however, our land policies failed to safeguard the permanent ownership of family-sized farms by the actual operators who farmed them. The land speculator was a pernicious counterpart of our early land settlement activities. Along with the pioneer squatter and homesteader was the speculative "land grabber," into whose hands soon fell much of the best virgin soil of America.

The recent report of the Land Planning Committee of the National Resources Board declares: "The operation of farm land by the owner was no doubt the ideal of all who favored liberal land policies. European tenant-ridden countries were cited in contrast with America, where every man could sit under his *own* vine and fig tree. It is easy, therefore, to understand the feeling of consternation which prevailed when the census of 1880 revealed that over one fourth of our farmers were no longer owners but had somehow become tenants in spite of homestead and other liberal land laws." By 1930, about 53 per cent. of our farmers operated leased land, and 42 per cent. of them rented all the land which they operated. The forces of depression appear to have increased this proportion, so that to-day it is estimated that not less than 45 per cent. of all our farmers are tenants.

The consequences of the failure to safeguard the principle of farm ownership by the operator of the farm is emphasized by the rapid development of farm tenancy in the states most recently settled under the homestead system. In North Dakota, for instance, where a large percentage of the land was homesteaded in the latter part of the last century, over 34 per cent. of all farmers in the state are tenants. The same development occurred in South Dakota, where almost half the farmers are now tenants. In Oklahoma, one of the last states to be opened for settlement, about two thirds of all farms are now operated by tenant farmers.

Our federal reclamation policy was also urged as a means of creating farm homes operated by owners. Nevertheless, there was the same failure to safeguard the system against the land speculator and the absentee landlord. Consequently, we find that about 40 per cent. of the farms on federal reclamation projects are operated by tenants.

The growth of tenancy is all the more serious because in the main it has occurred on the better lands in each of the principal regions of the country. In some of the best prairie counties of Illinois, for instance, you will find 70 to 80 per cent. of the farms operated by tenants. Tenancy is closely associated with

the specialized production of the major cash crops, the surplus of which has been troubling this country for more than a decade. Because it is associated with commercial farming and specialized crop production it is closely associated with and related to that other great evil of our land system—land speculation.

The fact that the tenant farmer has been intrusted with some of the best soils of the nation is especially serious because a large proportion of our tenants have little permanent interest in soil conservation. The average period of occupancy by tenants is only a little more than four years. Since few tenant contracts provide compensation for improvements made by the tenant and since both landlord and tenant are usually interested in the production of cash crops, it follows that in general tenancy is largely responsible for the serious and progressive depletion of soil fertility. We can hardly deal fundamentally with erosion and other types of soil wastage until we bring about a change in the relationship of tenant farmers to the lands they operate.

Some of the worst characteristics of the American tenancy system are found in the South. A great many people think nearly all southern tenants are Negroes. On the contrary, of the 1,800,000 tenants and croppers reported in the sixteen southern states by the 1930 census, only 700,000, or less than 40 per cent., were Negroes. Notwithstanding the tremendous increase in tenancy which occurred in the South between 1920 and 1930, all the gain was brought about by an increase in the number of white tenants. In fact, there was a slight decrease in the number of Negro tenants and croppers between 1920 and 1930, but there was a gain of 69 per cent. in the number of white croppers during that decade. A large number of southern owners and share tenants, particularly white owners and tenants, were forced to revert to the propertyless status of croppers by the agricultural depression which started with the fall of prices in 1920.

The disintegration of the farm system in the South, particularly the plantation phase, has become progressively more rapid since the world war. Factors which contribute to this include the increased mechanization of cotton production, especially in the western areas and in the alluvial portions of the lower Mississippi Valley; adverse influence on older areas of the competition in cotton production by the newer western areas; soil erosion and depletion of soil fertility from the one-crop system; the gradual depletion of timber resources which formerly supplied employment and income in many areas; a series of price crises since the world war that impaired the ability of many landowners, supply merchants and plantation operators to supply their tenants, and the pull of industrial employment which attracted labor from the South until the advent of the depression in 1929.

Since the depression, the displacement of Southern tenants and the increase in the number of rural "squatters" has been sharply increased. This was a condition with which the AAA was confronted when the first program was inaugurated to increase cotton income in 1933. We recognize that the operation of the cotton program has probably added to the immediate difficulties, just as relief policies have injected additional complications into the usual tenant and farm labor relationships. It is inevitable in a period of emergency that such disturbances should occur. But we should realize that neither the AAA programs nor any relief program can really come to grips with the fundamentals of these conditions. At best, anything we might do either through the AAA or relief would be temporary palliatives.

The present conditions, particularly

in the South, provide fertile soil for Communist and Socialist agitators. I do not like the bitterness that is aroused by this sort of agitation, but I realize that the cure is not forced violence or oppressive legislation to curb these activities but rather to give these dispossessed people a stake in the social system. The American way to preserve the traditional order is to provide these refugees of the economic system with an opportunity to build and develop their own homes and to live on the land which they may call their own.

In the South, as in many other regions, the real problem is to reassociate labor, land and capital in such manner as to enable the people to maintain a better standard of living than formerly under more wholesome conditions of operation both for the people and the land.

We have been talking about the evils of farm tenancy in this country for a great many years. It is high time that America faced her tenant situation openly, and pursued a vigorous policy of improvement. Studies made by the Department of Agriculture, state experiment stations and other research agencies have repeatedly shown that in communities where tenancy is extensive there is an unusual degree of rural instability and lack of a well-knit social life. It is almost impossible for tenant families who move from place to place every two or three years to participate in the activities of schools, churches and other similar rural institutions.

I do not mean to imply that all tenant farmers are poor farmers or that all of them are migratory and unstable. Perhaps the best type of tenancy in America is that which arises when a farmer retires and rents his farm to a son, a son-in-law or some other relative. In such cases the owner usually lives near-by and both he and his tenant relative are interested in the upkeep of the property. The owner continues to exercise considerable supervision. The tenant, after his period of apprenticeship, is likely to inherit the property or acquire it through some other family arrangement. This kind of relationship is to be found on about 19 per cent. of the farms of the United States, and it is especially prevalent in the Corn Belt and dairy regions. In one or two states as many as two fifths of the tenants are related to the landowners. There are also many other landlords not related to tenants who live near their farms and exercise a wholesome influence on the system of farm management.

Nevertheless, even in the Northern States a great deal of tenancy is characterized by instability of occupancy, absentee landlordism, soil exploitation and lack of identification of the tenant with community life.

It seems to me that it will be virtually impossible for America to develop a rural civilization which affords security, opportunity and a fully abundant life for our rural people unless she acts to convert tenants of this sort into owner farmers. It is extremely unlikely that a satisfactory and stable rural civilization can be developed in communities where the land is owned by absentee landlords interested primarily in profit and farmed by tenants who are willing, if not encouraged, to mine the soil and allow the buildings to decay, with the thought that they can move on to a different farm every two or three years.

If I understand correctly the general philosophy underlying the bill introduced by Senator Bankhead to create the Farm Tenant Homes Corporation, it is aimed at going back to the old principles, intended but not realized in our early land policy, of trying to get the good farm land of America into the hands of owner-operators who live on family-sized farms, but with proper safeguards to prevent the land from again becoming a football of speculation. I am confident

that the provisions of this bill, if it is enacted into law, can be administered in such a way as to bring greater individual opportunity to hundreds of thousands of our tenant operators; check the growth of rural tenancy in this country; and bring much greater stability and security to thousands of farm communities. Moreover, it would be of substantial aid in dealing with our problem of surplus cash crops. Our recent experiences have shown that a reduction of acreage in a tenant community tends to create agricultural unemployment, with some of the evils characteristic of urban unemployment. However, in communities where practically all farms are operated by owners, the acreage reduction programs have brought about a greater diversification of farming, with a resulting higher standard of living, and have aided in increasing soil fertility.

No better method of aiding our tenant farmers can be undertaken than to give them a secure form of tenure on a family-sized farm; aid them in carrying out a farm and home management program that will yield a reasonable cash income; and, at the same time, create a farm and home unit as a permanent, desirable and secure place to live and rear their children.

It is imperative that the administration of a bill so far-sighted and socially desirable as this Bankhead bill be carried out in accordance with sound principles of farming and in the light of the best experience in dealing with rural problems. I take it that the main purpose of the bill is not to make available a large sum of liberal credit to be promiscuously used in aiding tenants to purchase farms, without any thought as to the resulting consequences of their newly acquired ownership. To transform some of our inexperienced and undesirable rural tenants into immediate owners, by the simple expedient of loaning them substantial amounts of money on very liberal terms, might create more social problems than it solves. On the other hand, by following a sane and conservative program for aiding desirable tenants in becoming owners, and by helping the inexperienced ones to follow sound farm management practices, we shall be able to aid them in buying a farm which they can retain as a permanent home.

For many years, practically all European countries have had policies for aiding tenant farmers to become landowners. About 60 years ago, Ireland entered upon a program of abolishing her tenant system, which was one of the most abominable that has ever developed in the Western world. By instigating an active policy, in which the part played by the government was to buy large estates and resell them to tenant operators on a long-time payment plan with low rates of interest, Ireland was transformed from an island of poverty-stricken tenants into a nation of independent farm-owners. The resulting social and economic gains have been enormous, and the losses to the government have been negligible. The customary rent paid by the Irish tenant was simply transferred into a payment on his farm, to which he gained title only after the last payment was made. In a similar manner, Denmark, Finland, Germany and other European countries have made government loans available to agricultural tenants as an aid in purchasing farms.

England is practically the only country in the Old World which has not had an active governmental policy of aiding tenants to become owners. She has accepted tenancy as a permanent institution, and developed measures to alleviate its customary evils. For many years there have been laws in England which provide for fair rents, a long and stable period of occupancy by tenants, and which compel landlords to compensate tenants at the termination of the tenancy

for improvements of the land and buildings. The compensation paid to tenants by landlords for building up the soil and improving buildings has been an important factor in maintaining a stable agricultural economy in that country.

It may be argued by many people in this country that to aid a tenant in becoming an owner on a shoe-string of credit is socially undesirable and economically unsound. Without governmental assistance, however, it is often extremely difficult for tenants to obtain holdings of the proper size to fit their ability and family labor supply. Moreover, it has been virtually impossible for more than a decade for many of our energetic and ambitious farm boys to acquire capital sufficient for the customary down-payment on a good farm. Many tenants with years of farm experience have been earning such a small margin, after they paid their rent to the landlord, that they were virtually forced to continue through life as tenant operators. The percentage of tenants who are more than 55 years old has been increasing in this country for several decades. Now we have about 375,000 who are over 55 years of age. Many of these people have struggled toward ownership for years, and yet in their old age have no home of their own and no more security than when they started as farm laborers.

An active government program aimed at making owners out of desirable tenants, through a system of long-term loans which can be repaid by taking the ordinary rent as payments toward the ownership of a farm, is a thoroughly sound and justifiable procedure for creating greater security and more desirable homes for our rural tenant population. During the period when the purchasers are slowly creating an equity in the farms they operate they will have all the security of an owner and should develop a real and lasting interest in maintaining their homes and permanently participating in the social life of their communities.

In short, I believe we need legislation which has as its aim the creation of a substantial group of farm-owners out of our present tenant class. I know of no better means of reconstructing our agriculture on a thoroughly sound and permanently desirable basis than to make as its foundation the family-sized, owner-operated farm.

THE LIFE IN THE SOIL

By CHARLES THOM

PRINCIPAL MYCOLOGIST, DIVISION OF SOIL MICROBIOLOGY, BUREAU OF PLANT INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE

In March and April the urge to plant something strikes some fifty million Americans. It is the same urge, whether I plant three seeds in a tomato can or you plant a thousand acres of wheat. We put our seeds into the soil and watch them grow. But how much thought do we give to the soil in which they grow? Is it fertile or sterile? Is it an inert mass, or is it teeming with life?

Get down and look closely at the surface of your patch of soil. You saw no weed seeds when you dug it, but at least a half dozen weeds are coming up for every seed you planted. Perhaps a cluster of moss plants appears. Then you see a patch of green or blue-green right on the surface—some alga is growing freely on the moist earth. Traces of last year's crop—decaying leaves, grass or weed stems are slimy with bacteria or show patches of black or brown or bright-colored mold.

Then you see a hole or two, suggestive of some animal which prefers darkness, at least when we are around. Thrust a trowel under one of the young plants, lift it out unbroken and examine the ball of earth about its roots. If you act quickly you may catch a wriggling earthworm or a grub or two, hastening from harm's way into unbroken soil; half a dozen other creeping or scurrying animals are trying to escape. Then look a bit closer, or drop a lump of earth into water, and examine it closely with a hand lens. Another series of worm-like things just about at the limit of visibility to the naked eye pass in review.

These visible forms are gross destroyers of plant and animal material; earthworms and insects swallow and digest part of this food. They drag some of it into their burrows. Some kinds feed at the surface and only retreat below for protection. Others work entirely below ground. Their holes ramify through the top soil and go deep enough to ensure contact always with moist earth. Such holes act as ventilating flues which carry air in and gases out. Rain water floods them and drives the owners to the surface, where the birds get some of them, while multitudes dry up and lose their lives. Some of these animals are definitely useful, some are definitely destructive. We need to know them therefore and to know for any particular soil what types to encourage and what types to destroy. But we have only begun when we talk of the bugs and worms which we can see with the naked eye. We pass our seedlings over to the laboratory.

The microbiologist uses his microscope and his staining materials. He washes the dirt off young roots and examines their tips—each rootlet and each root hair is fringed with microorganisms, including bacteria, yeasts, molds and amoebae. Life and growth are transient things: The active work of the root is done by delicate living cells in direct contact with earth. These cover the freshest and newest inch or two of each rootlet. Only a little way back from the very growing point, cells which have done their work are already dead and are filled with bacteria and mold threads; they are well along in the process of decay. Back of that, the root becomes a hold-fast to keep the plant secure, and conducting tissue to link the green parts above with a complex collecting system of rootlets in the soil, which

gather its water and plant food. All around these complex branching systems swarms of microorganisms line every pore of the soil and attack every waste or worthless bit of vegetable matter. Such organisms form a total of many millions to the average teaspoonful.

Rootlets penetrate every clod of the surface soil and are readily observed in the deeper layers. Some roots can be followed down several feet. Three feet down on a roadside bank, we found a hole about an inch in diameter. Examination showed a lining of bark, out of which a large root had rotted away—microorganisms had gone right along with the root, and destroyed it when the tree was cut down to build a road.

In my laboratory, I have a chunk of Virginia clay, painstakingly dug by a chemist friend of mine to show how a root had bored its way through a mass of hardpan situated about 3 feet down in the earth. That layer was so hard and dense as to be almost impervious to water, yet the root got through it. He showed other masses with the roots still in them. This root had finally died, and bacteria had rotted it away, but the walls of the hole were discolored by bacterial slime and soil solution that had followed the root channel. In other blocks he showed how several generations of roots had gone through hardpan into the earth beneath through a single channel. Such root channels are factors in the distribution of water and microorganisms into the deeper layers of the earth.

This picture of soil population relations is further complicated if we remember that there are a thousand and more varieties of soil in the United States and each presents somewhat different conditions for growth; hence we must expect to find a multitude of variations in the proportional number of various elements in the population. As a conspicuous example of contrasts, I have seen places where one could pick up a quart of earthworms in a very small area after a rain, while a soil man working in one county in Kentucky declared he could not find enough worms in the whole county to go fishing once.

The distribution of microorganisms in relation to the soil particles is also important. To get a picture of this distribution some of us stopped in a cut along the highway and broke fresh vertical slices from the top of the bank. Then the inventor who went with us set up a microscope designed to examine the cut face of the soil. By a special device he threw a strong light into each little spot at which his microscope pointed, then each of us looked into the broken face of the soil. Such a cut is not smooth; the soil is composed of innumerable particles of varying size and shape and hardness, packed together, but with cracks or pores among them. Some of those particles are shapeless—amorphic, some are grains of sand or crystals with smooth or broken facets; the whole forms a weird mixture of the flotsam and jetsam of ages of rock disintegration and of life activities. We focussed our microscope upon some of the grains of sand. Each facet was partly masked or smeared with translucent material; the chemists call it colloidal slime. We looked deeply as we could into the pores, and saw, not sharp angular cracks between clean sand particles, but channels winding and twisting among grains of soil smeared over with slime and cemented together by it.

Then we set our microscope upon a stump, pried out an unbroken clod and put it under the lens, arranging a mirror to throw a beam of sunlight on the spot at which the microscope was pointed. Down in the pores of the soil we could see bits of mold protruding, patches of varicolored growth, and here and there some minute animal retreating from our unwelcome intrusion.

Next we picked out some of the smallest and brightest of the sand grains seen,

rolled them upon a glass plate, stained them and looked at them with the microscope. Their surfaces were dotted with microscopic masses or colonies of bacteria or yeast-like organisms, and often streaked by threads of mold. Tufts of mold stuck out into the open spaces between the grains. Cultures from this type of crystal show thousands of colonies of a weird mixture of microscopic living things.

What are these organisms? Whence do they come? And what do they do where we find them? Identification of kinds or species produces a varied list of bacteria, molds, protozoa, algae and microscopic animals of higher groups. Thousands of species of molds and bacteria can be found above ground. They are in or on everything; they infect; they rot; they ferment. Sooner or later all of them are carried into the soil on waste materials. Many of them perish there, but if one hunts long enough, widely enough and carefully enough, great numbers of them can be recovered and related to their source.

These organisms carried in from above are not the whole population, for there are a myriad more already in the soil—kinds which are at home there. These are found in every soil—not just in a few places.

Some review of the everyday business of this complex soil population may be presented. In all ages, the worn-out, the worthless and the offensive have been dumped upon the ground or buried; nearly all disappear. We commonly say that some things rot, and others corrode. The soil is the universal leveller. The monarch of the forest, the moss in the cleft of the rock, the mastodon and the microbe have played their temporary parts; their remains went back to the general supply of raw materials, sooner or later to be used again. How these complex structures went back to simple forms, what agents were active in the process and what chemical changes were involved are only partly answered.

If we take a sample from unplowed earth from a reasonably fertile field and subject it to the examination of the bacteriological laboratory, it will show roughly 20 to 40 million microorganisms to the gram. When put into a testing chamber, it will give off measurable amounts of carbon dioxide. The organisms are not only present, but they are active. If we test fresh samples at regular intervals we will find changes in numbers, changes in group representation, and changes in rate of carbon dioxide evolution, but as long as the field remains unplowed, a general level of activity is maintained; the changes are minor. A kind of biological balance has been reached, based upon the growth conditions presented.

If we plow and plant that ground, the whole situation changes; the top six inches of soil are broken up; last year's plant remains and the top soil with its myriads of organisms are turned under or mixed with fresh soil; air is stirred in. The top six inches are now loose or porous instead of firm. Then we find that myriads of microorganisms that had lain quiescent in the deeper layers spring into activity.

If there be one feature of a microbic population more striking than any other, it is this capacity for sudden and tremendous increase in numbers and biochemical activity when conditions become favorable. A crop of clover or vetch plowed under begins quickly to decay. The number of microorganisms found in the decaying mass may reach billions within a week, then drop back more or less quickly toward some normal figure. The slimy residues produced help hold the soil particles together against wind and water. If large amounts of material were plowed under, totals of population in the whole plowed mass may remain two to several times higher than before. Cultivation keeps the ground stirred, keeps up aeration and favors the maintenance of this increased activity. If a sample is put

into the test chamber at the height of such activity, the rate of carbon dioxide production suggests a fire; quickly fermentable matter rapidly disappears; the excess of carbon dioxide escapes into the air, where most of it serves no immediate purpose. These activities are definitely destructive.

Under intensive cultivation, as in continuous cereal farming, reserves of soil organic matter are attacked; supplies of nitrogen are reduced. As long as such reserves remain ample, large crops can be grown. But if we continue this process year after year without replacing material destroyed by such activity, the supplies stored in the original soil in past ages can be so depleted as to interfere with crop production.

This is exactly what happened in our prairie states. I can remember when many farmers believed fertilizers unnecessary. I have seen manure dumped into the river. Out in Nebraska and Kansas they have measured their lost fertility in cultivated areas against what they still find in unbroken prairies. From some of those farms half the material stored up in ages past is gone in a single generation of grain farming. Such losses eventually upset the balance and troubles begin to appear. These take various forms, some of which may be mentioned.

Down in the hotter sections of the Southwest, cotton root-rot has long taken a heavy toll—forty million dollars was the penalty reported last year. King, of the Bureau of Plant Industry, working in Arizona, found that where he put a lot of stable manure or farm waste in a deep furrow below his cotton, the disease was controlled. Over in Texas, another group of workers broke up the subsoil and stirred in a crop of sorghum with the same result. In the prairie states, wheat has been pestered by a root-rot fungus so mean that men call it "take-all"—it leaves the farmer nothing. Fellows, another Bureau man, seems to be proving that mixing hen manure into the soil controls the "take-all" fungus.

What do these observations mean? These destroying fungi are not new organisms; they were there before the white man came. But the land was in native grasses; a natural balance seemed to hold between green plants, bacteria, fungi and all the rest. Then man came along with extensive farming methods; he destroyed the original sod; he speeded up some processes; he depressed others; as a result some organisms run riot because those which should hold them in check are suppressed.

These are but a few illustrations. Similar situations can be found with endless variation if you go out and look for them. They are brought out here as evidence that while plowing and planting, fertilizing and hoeing are directed at flowers or vegetables, orchard trees or field crops, they also affect a world of microscopic life unseen but not unimportant to the farmer.

Your patch of soil and mine present their separate problems. Each has its peculiar natural population above ground and below, but when we decide to grow one particular choice of crop we must survey the whole problem if we are to get the best out of our soil. We need to know the kind of fertilizer and cultivation required by the particular crop; we must give due heed to the combination of mineral and organic materials which make up the particular soil; but we need also to see in that soil the home of a complex micropopulation, among which are species which may help or injure that crop and which must be handled correctly, if we are to continue to get the largest return from our investment.

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THE STORY OF MAN

By HENRY FIELD

FIELD MUSEUM OF NATURAL HISTORY

THE story of man—past, present and future—concerns every living person. Man's past, however, is a much longer story than the average person appreciates. Many people realize that in order to understand the present and plan intelligently for the future we must have some knowledge of the past. But those same people may turn to ancient Egypt, to Greece and Rome, to William the Conqueror and Alexander the Great, and feel that they are going back to the beginnings of history.

Man's struggles and victories began hundreds of thousands of years before Alexander undertook his brave expeditions—and those struggles were against greater odds, those victories more inspiring, than any man has known since the time that history was first written.

Let us review in outline the main features in the dramatic story of man during the past million years. In passing from the darkness of our knowledge of the first men down to the dawn of history, we are continually aware of the limitations of available information. We owe an eternal debt of gratitude, however, to the scientists who have contributed fragmentary pages to the book of knowledge, which is the story of man.

Who was the first man, and where did he come from? It is difficult to trace the unwritten record of man, since many of the details lie buried in the earth or are lost beyond recall. During the past few centuries it was believed that the world was created in the year 4004 B.C. and that man was the result of special creation. At the close of the first third of the twentieth century scientific workers have shown absolute proof that hundreds of millions of years passed before any animal that could definitely be recognized as human had evolved upon the earth. Study of both living and fossil forms reveals the fact that a labored evolutionary progress from simple one-celled organisms to many-celled, from fish to amphibians, from reptiles to birds and mammals, was necessary to produce the most advanced form—man.

Branching off from the main primate stock several million years ago, our ancestors possessed many physical characteristics in common with the anthropoid apes. As time passed, the gap between the two branches grew ever wider. We do not know just when or where the first humans evolved, but the evidence that man did develop in such a manner is undeniable, and gradually the facts are being pieced together to form an increasingly clear picture.

On the northern border of Europe—in England—and on the eastern fringe of Asia—near Peiping—the earliest traces of man have been found. Primitive evidence has also been unearthed in Africa; so that even hundreds of thousands of years ago mankind had spread far and wide. The data, consisting of fragmentary human remains, stone tools, animal bones and the charcoal of hearth fires, are still too few to draw any but the crudest picture of the earliest members of the human race. There is abundant evidence of man's existence a quarter of a million years ago, however, in western Europe. The climate was mild. The elephant, rhinoceros and hippopotamus were the dominant forms of

animal life. The man of that period must have been rugged, powerful-jawed and ferocious in appearance. Small in numbers and physically weak in comparison with the creatures which surrounded them, the earliest hunters were forced to use ingenuity and their powers of reason in order to maintain themselves in a hostile world. They had knowledge of fire, which enabled them to keep off marauding animals at night. They developed the art of flaking flint to a relatively high degree of perfection. With only wooden spears and handaxes for weapons, however, they must have often been more hunted than hunter. It is interesting to recall that these primitive hunters—the Chelleans, as they have been named—could walk from France to England, because at that time the English Channel had not been cut by the sea.

In Field Museum eight large dioramas, with figures realistically modeled by Frederick Blaschke and backgrounds painted by Charles A. Corwin, portray graphically the main stages of man's development. The first diorama is a Chellean scene in northern France some 250,000 years ago. In the foreground, squatting beside a fire in the shelter of a large rock, are two hunters, one of whom is chipping a flint handaxe preparatory to the hunt on the morrow. In the distance is a meandering river, and on the opposite bank three elephants are frightened from their watering place by the smell of the dense smoke of the fire. Farther upstream a hippopotamus can be seen on the bank. Near the skyline, a magnificent stag, anxiously watching the flickering light, protects his hinds from the scent of danger. Stealing through the underbrush, a pack of wolves is barely distinguishable. This moonlight scene recalls vividly man's plight, as well as his strength, some quarter of a million years ago.

Development during the following tens of thousands of years was extremely slow. A long interval of time found Europe under the effects of a cold climate, the approximate date being 50,000 years ago. The mammoth, reindeer and other cold-loving animals wandered over western Europe. Then Neanderthal man—a new race—made his first appearance. He was about five feet four inches tall, thickset, with a large head and short limbs. The head, thrown slightly forward, was carried in that position by strong neck muscles. To our eyes his face would have had a fierce expression, emphasized by the enormous brow-ridges, small, round eyes and broad, flat nose. It is interesting to note that the lobe of the brain associated with the power of speech was little developed, as compared with that of his modern brother.

Neanderthal man lived in caves or rock-shelters for warmth and safety. A fire, built near the entrance, formed excellent protection against cave-lions, bears, hyenas and other animals. Neanderthal man was probably the first to seize a woman and protect her from animals and other men. This was the beginning of family life—a great step forward!

The struggle for existence was hard, and there was no time for relaxation and the development of the artistic sense. Stone and bone tools show marked improvement in technique. One Neanderthal ceremonial burial suggests a reverence for the departed and a belief in a future life, because a stone weapon was found in the hand of the skeleton, and apparently fresh meat had been placed inside the grave. In another locality charred bones of human beings suggest cannibalism.

The hunters of this period developed the use of fire, a new variety of flint and quartzite implements, the beginning of family life, and they believed in a future existence. Considering these important advances, we must recall with pride the struggles of our Neanderthal predeces-

sors against an inhospitable climate and savage animals.

We now pass rapidly over the next 20,000 years, and find Europe still under the influence of a bitterly cold climate. A new race, called the Crô-Magnons, swept into Europe from the plains of Asia. They were of magnificent physique, tall in stature, with a large cranial capacity. During this time the struggle for food became less intense, due to a more abundant supply. As a direct result there was time for the development of a latent artistic sense.

Here was the dawn of art. In their cave-dwellings the Crô-Magnons began to adorn the walls with engravings and paintings by means of a flint tool or by application of some colored pigment of red, yellow, black or white. They made accurate reproductions of the animals which they hunted, and occasionally they represented human beings in the innermost recesses of the caves. Personal ornament was also a new development. Necklaces of reindeer teeth, sea shells or fish vertebrae were worn. Ivory beads fashioned from the tusk of a mammoth probably corresponded in value to modern pearls. We find their dead buried with their finest shell ornaments, their most useful tools and weapons, presumably to make an imposing appearance in the new life beyond the grave. In several caves we find the imprint of a red hand on the wall, sometimes with the fingers missing. The motive which prompted this terrible mutilation of the hand is unknown, but we can give some modern parallel instances. For example, in the early nineteenth century travelers among the Bushmen in South Africa recorded that the women cut off their little fingers with stone knives as a sign of mourning. This was to ensure a long career of feasting after death or a safe passage to the next world. Among other tribes, this mutilation was a sign of caste, a tribal mark, or a cure for sickness. Catlin described the removal of the forefinger of the left hand during the initiation ceremony of the Mandan Indians. On the island of Tonga in the Pacific area Captain Cook reported that fingers were sacrificed to propitiate the god Atoa.

At the close of this period the climate grew still colder. Horses and wild reindeer were the chief sources of food supply.

Let us visit one of those caves in southwestern France to examine some of the famous cave paintings. Cave equipment, such as matches, candles, acetylene lamps, ropes and rope ladders, are carried to the mouth of the cave by guides. The lamps are lit and in single file we enter the dark mouth of the cave. It is relatively easy to walk the first few hundred feet. The cave walls are damp and there is a constant drip of water from the roof. The men in front are silhouetted against their swinging lamps and their echoing voices sound weird and eerie. Traveling becomes increasingly difficult and progress slower as we slip and slide on the wet floor. There are places where a rope is necessary to ascend the steep and narrow parts of the cave. By the light of our candles the beautiful stalactite curtains appear majestic. Finally we reach a rock gallery where, in the flickering light, we see the impressive engraving of animals made by prehistoric man many thousands of years ago. It is almost certain that these paintings were inspired by some magico-religious motive. This may be illustrated by the following example: A hunter is going to seek reindeer tomorrow. Food has been scarce and his family is hungry. After dark he goes to the medicine man of his tribe, who leads him into the cave, which fills him with awe. After a long, perilous climb, during which the sound of running water and strange echoes have duly impressed the hunter with the sanctity of his surroundings and the fearlessness of his leader and master, they reach the

innermost chamber. Here the medicine man makes incantations before the picture of a reindeer painted on the wall. To the primitive mind the spirit of the living animal is embodied in the painting. The medicine man therefore has power over the wild reindeer, a power which he transfers to the hunter by means of ritualistic incantations. Next day the hunter goes out with renewed confidence and is successful, as the medicine man has predicted.

We must pass from the development of an artistic sense and appreciation to the next stage, where the dog first became man's faithful friend at home and ally in the chase. The domestication of animals had begun.

Early Neolithic or New Stone Age times witnessed the first practice of agriculture and the manufacture of pottery, probably by the women. The domestication of animals and the cultivation of plants made settled community life possible. Without these epoch-making developments some ten thousand years ago there could be no great cities. The Neolithic hunters also learned to grind and polish their stone tools. Then came the discovery of the use of metals. First copper, then bronze, iron and steel—the age in which we now live.

We must now focus our attention on part of the "Fertile Crescent," formerly known as Mesopotamia—the land of the Twin Rivers, the Tigris and the Euphrates. The evidence obtained by three Field Museum North Arabian Desert Expeditions, of which I was leader, indicate that some six or seven thousand years ago the climate of the Near East changed. I believe that the inhabitants of what is now the North Arabian or Syrian Desert were forced by lack of water to become nomads, as are the Beduins to-day; to move westward to the pleasant, watered valley of the Nile, or eastward to the fertile alluvial plain beside the banks of the Euphrates and Tigris Rivers. Under these favorable conditions civilization began. The Field Museum-Oxford University Joint Expedition, excavating at Kish near Babylon, discovered the earliest known tablet—six thousand years old—bearing incised pictographic symbols. There was the beginning of the written record—writing. The oldest wheeled vehicle in the world—a four-wheeled chariot—was also unearthed in a special tomb among the ruins of mud-brick houses and sacred buildings. Evidence of the great deluge—the Flood of Noah—was revealed. Once again scientific research confirms the greatest written word—the Bible. The great temple of worship built by Nebuchadnezzar came to light, to bear silent yet eloquent testimony to the attainments of these makers of history.

In Egypt a different form of civilization was progressing slowly. The story of everyday life in ancient times beside the banks of the Nile has been revealed by the patient and careful study of the archeologist. The great pyramid of Cheops, the Sphinx with its age-old riddle still unsolved, the magnificent stone monuments at Luxor, Abu Simbel and other ancient sites create an inspiring picture of the advanced cultural development of the Egypt of their time.

As we rapidly review the historical period, we recall the great civilizations of classical Greece and Rome and their direct contributions to the thought, word and deed of the twentieth century. In other parts of the world, in China, India and Persia, progress was being made along different lines. Then from the Birth of Christ, until one hundred years ago, the story takes definite shape, in which certain makers of history stand out in bold relief. The last hundred years begin with the great industrial revolution and conclude with the vast modern economic upheavals of worldwide scope. The age of steel brings rapid transportation and communication—speed, speed, speed—wheels of industry spin so fast that western civilization

has become giddy with speed and power. Labor-saving devices and time-saving machines rotate at high speed. What do we do with the time thus saved?

The nation must learn to adjust itself to this added leisure—this time on our hands. Education in its widest aspects is the real solution to this vital problem. If, in our leisure time, we can but realize with an ever-widening knowledge and maturer outlook that in spite of most divergent types all human beings are alike deep under the skin, then machinery has freed us for a worthy purpose. The superb sculptures of racial types by Malvina Hoffman in Field Museum demonstrate wide variations of Caucasian, Asiatic and Negro; but there is a fundamental unity of mankind.

The course of future events can not be predicted. Six thousand years of civilization do not seem to have been sufficient to check the instincts of fear and greed. But, let me say in conclusion, we can recall with pride the struggles of mankind during the past million years. This will give us courage for the future.

WHY TAKE THE SUN FOR GRANTED?

By Dr. DONALD H. MENZEL
HARVARD COLLEGE OBSERVATORY

WHY is it that almost every one takes fresh air and sunshine for granted? The depression may have partially destroyed faith in the old axiom that the world owes one a living. But it has not diminished the daily supply of breathing material, and the good old ultra-violet rays appear to be about as capable of producing a painful sunburn as in the hectic days of 1929. Every filling station advertises "Free Air." The public accepts both air and sunshine as "free." There is a general supposition that they have always been and always will be "free"—whether the date is 1,000,000 B.C., 1935 or 1,000,000,000 A.D. I propound the question: "Have we the right to take the sun for granted?"

As we look back over history we find evidence that men did not always have our present child-like faith in to-morrow's sunrise or in the return of summer. Certain tribes had special priests, whose duty it was to offer sacrifices to the sun-god who, angry at mankind, retreated southward in the fall, punishing the people with bitter weather. Some of the priests, no doubt, sincerely believed that the return of spring was due solely to their efforts. Others may have been skeptical. If so, their position was not dissimilar to that of the crying child who, when asked the reason for her tears, replied that she wanted to go to the movies. "But," objected the kindly inquirer, "do your parents ever take you to the movies when you cry like that?" To which the child replied, "Sometimes they do and sometimes they don't, but it ain't no trouble to cry."

What would be your emotions if a radio announcer were to interrupt your favorite program with this report: "Ladies and gentlemen,—we have just received word that the sun has gone out!" Just think what such a catastrophe would mean! That to-morrow would be dawnless! That the earth would henceforth be doomed to perpetual darkness! I hasten to assure you that the sun was shining when I entered this radio station and I have reasonable confidence that it is still shining, though I can not absolutely guarantee it because this broadcast room has no windows—and I am sure that the sun is not infallible.

What if the sun were really to go out!

Picture the confusion! How rapidly would nations forget their petty troubles and put their shoulders to the wheel in a valiant effort to save themselves! They would have to move swiftly. In the course of a few sunless days summer would change to winter. Snow would fall in the darkness. Lakes and oceans would freeze. Food and fuel would rapidly disappear and civilization would be destroyed in a few months at best. Eventually the atmosphere would condense, liquefy and freeze to entomb the entire earth with a thirty-foot casing of solid air. What is the chance that such a catastrophe may happen to us? Let us explore the sun and try to find out what it is made of and what makes it go. Perhaps we shall find an answer to our question.

The sun is a star, a great hot ball of gas. And, conversely, stars are suns. The other stars are faint only because they are millions of times more distant than our sun. I wonder how many of you have ever seen the sun. Really seen it, I mean. Of course every one is conscious of the fact that somewhere in the sky there is a dazzling blur that hurts your eyes when you look at it by accident. You may have seen the sun's disk late in the afternoon or early in the morning, when its light was greatly dimmed by haze. Or perhaps you saw it through smoked glasses when you were watching the last eclipse. A good way to see the sun, and in its natural colors, is to make a very tiny hole in a visiting card and cautiously examine the sun through this.

Now let us journey sunwards. By the time we reach Mercury, the innermost planet, we shall have to use a five-cent piece for a sun shade. Though this is not very large, the sun's increasing nearness is clearly evident by the rising temperature. Our thermometer reads over 600° Fahrenheit. We continue our journey until the sun fills more than half the sky, where it will take something even larger than a wash-tub to shield us from the heat radiated by this gigantic furnace. At this point we are less than 1,000,000 miles from the face of the sun—a hundred times closer than we were at the start of our journey. Our thermometer reads 5000° F., and we deduce that it would read 11,000° F. at the solar surface.

The sun looks like a great pot of boiling lava, though 11,000° is too high a temperature for any substance to exist in either the solid or in the liquid state. Hence, all that surface is gaseous! The sun is covered with a multitude of flaming gas-jets—fountains of fire that extend upwards sometimes thousands of miles. Yet it is not real flame in the sense that something is actually burning there. For the sun is too hot to burn. If we could convey to the sun great quantities of the ordinary products of combustion—carbon dioxide, smoke and water vapor—we should see the stuff unburn before our eyes. The carbon dioxide would break up into gaseous carbon and gaseous oxygen. Then, if we could separate these two substances, and transport them back to the earth, we should be able to heat our houses next winter with the coal we burned last winter.

The outer layers of the sun are partially transparent, which calls to mind the earth's atmosphere. But there the analogy stops. In the solar atmosphere gales of a thousand miles an hour and sun-spot whirlwinds even more violent are frequent. The fiery gases consist not only of oxygen and nitrogen, the familiar constituents of ordinary air, but also of iron, aluminum, lead and other substances that are usually solid upon the earth. The sun is very large. Its diameter is more than 100 times greater than that of the earth. It contains a great many atoms. If the silver just of the solar atmosphere could be extracted and brought to earth, rare as that element is, it would form a ball

more than a quarter of a mile in diameter. It would weigh almost a billion tons and its value would be inconceivable.

But the sun is something more than just a conglomeration of atoms—a mixture of chemical elements. It is a machine in the broadest sense of the word—a cleverly designed dynamo that furnishes light and heat to the universe as a whole. True, it is not man-made. It is not a combination of wheels, levers and wires. Nevertheless, somewhere far below the solar surface, there is some sort of mechanism for manufacturing energy. We do not know of just what it consists, but we know it must be extremely powerful. The rating of the solar engine is five hundred sextillion horsepower (500,000,000,000,000,000,000,000) or 80,000 horsepower for every square yard of the solar surface. Only one part in 2,000 millions of the total radiated energy actually strikes the earth, but even if the fraction falling per day upon an area one mile square could be converted into electricity at the rate of one cent per kilowatt hour, its value would be more than two hundred thousand dollars.

These geyser eruptions, the stormy areas we call sun-spots and the form of the sun's corona halo appear to be related in some mysterious manner. They all vary, with a period of about eleven years. We can not tell whether this variability constitutes a menace or not. The earth can not help but be affected to some extent by these conditions. We know that the aurora borealis flares more brilliantly when large sun-spots are present. Simultaneously magnetic disturbances cause interference on the transatlantic telegraph. The rainfall of past centuries, as recorded in the growth of tree-rings, appears to reflect the eleven-year sun-spot cycle. Sun-spots may be called upon at any time to explain a New-England blizzard, a southern drought or "unusual" weather in any section of the country. It has been proved that financial cycles have a period of about eleven years and sunspots, accordingly, have been blamed for the depression. If there is some indirect connection I am unable to discover it. I wonder why no one has thought of suggesting the converse—that the depression may have been responsible for sunspots. Many of us had spots before our eyes in 1929.

The reliability and permanency of the sun are remarkable. Frozen in the rocks is a continuous record of life upon the terrestrial surface—from the age of delicate protozoa and animalculae through the period when the earth was dominated by dinosaurs and other Mesozoic reptiles, and on to the modern era and civilized man. Throughout this enormous epoch—five hundred million years or so in length—there is no evidence of the sun's having been shut down for repairs. During this time the intensity of solar heat has never increased to twice or fallen to half of its present value. Otherwise the continuity of the geological record would have been broken. This means that *each* gram (each thimbleful, let us say) of the sun has, within the lifetime of the earth, accounted for more than 1,000 million calories, enough heat to boil ten tons of water. Obviously, this is far greater than could be produced by any *burning* process, such as the complete combustion of an equal mass of pure carbon and oxygen or, for that matter, by any other chemical process. It would be like trying to heat enough water for a dozen baths with the aid of a single match. The magnitude of the energy source is one that may well arrest the attention and the imagination of the engineer. If he could only discover this method of energy production and harness it for mankind, all questions of power supply would be solved for future generations.

Many of us will consider ourselves lucky if our 1929 cars will last only till

the end of the depression. An automobile that has been in service for thirty years is awarded high honors and put in a museum, while the sun's marvelous record of billions of years of continuous service goes unnoticed. This is hardly just. Not that I should recommend putting the sun in a museum—at least not just yet. The Harvard Observatory, feeling strongly in the matter, has placed a symbolic solar motif over the door of the building containing its largest telescope.

Despite such apparent dependability we can not assume that the sun will keep on shining forever. The old maxim that we never get something for nothing is especially true in science. "Free air" for your tires costs the garage owner for equipment and electricity. And "free sunshine" costs the sun a part of its store of energy. Vast as this store is, it can not be inexhaustible. How long the sun can continue shining at its present rate depends upon the type of energy supply—and of this we know practically nothing. Many theories of the origin of the sun's heat have passed in review and have been discarded as inadequate. The combustion theory, as I previously mentioned, is of this type, since it could provide energy for only a few thousand years. Likewise the hypothesis that the heating is due to impacts of meteors has been thrown into the rubbish heap along with the contraction and compression theories.

We appear to be driven to the conclusion that the sun keeps itself going by a process of self-cannibalism. The sun is actually eating itself up, turning its matter into energy, which is radiated away into space and irretrievably lost. By this hypothesis we may fix an upper limit beyond which the sun can not exist—for the sun can not do more than consume itself entirely. If the sun continues to radiate as at present, we find that within ten million years or so, it will have burned itself out completely. Perhaps by a more prodigal expenditure of energy in its old age, the sun might be able to survive longer, but its warming effect on the earth could not be reduced much below its present value if life is to survive. And, of course, the sun may not find itself entirely edible. If only a small fraction of its mass is convertible into energy then the estimate must be proportionally reduced. I should be very much surprised, however, to find the sun fading appreciably before the elapse of many billions of years. You will have to wait with me, I fear, to see whether this prediction is verified. The date is sufficiently far in the future that I doubt whether many of you will worry about the possibility of my having to drop a couple of ciphers from my estimate. A billion years appear to be a short time in the cosmic scheme of things, long as they may seem to you, who, if you chance to be thirty-one years old, have lived about a billion seconds.

The processes I have been describing so far picture the sun as living a normal sort of life and eventually dying of old age, and a ripe old age at that. I can not guarantee, however, that a catastrophe may not intervene to take the sun off in its prime. The chances of hitting another star are practically negligible. The celestial accident insurance rate must be fairly low, much lower than the rate for sickness insurance. Stars may collapse or explode, and we can not be certain that our sun is immune. As a matter of fact the sun's face is pretty well spotted at times; it has skin eruptions—or perhaps they may be more than skin deep; its temperature fluctuates up and down by a few degrees. Yes, we might say that the sun has a mild case of periodic fever. When its temperature is up we have more spots and more eruptions. About eleven years elapse between the times of highest fever and maximum spottedness.

Unfortunately we can not tell how wide-spread this particular type of stel-

lar disease is. All the other stars are too far away for us to get a good look at their faces. We have some reason to believe, however, that many stars are similarly affected and we need not fear that the sun's demise is imminent. Some stars appear to be afflicted with a sort of pulmonary trouble, for they alternately inflate and deflate themselves, like a rubber balloon being blown up by a child who insists on sucking in on every breath. Such a star would not make a very good sun, for its rate of radiation is not constant. We should boil one day and freeze the next. We have little fear of our sun's falling heir to stellar asthma of this kind, since most of the stars that exhibit these symptoms are very much bigger and brighter, as well as more bloated than our sun. There are some stars, like R Coronae Borealis, that go along for years apparently normal and then suddenly decide to take a rest and hibernate. They fade away to a thousandth or so of their usual brilliance, and after a few months' or a year's vacation get back on the job. These stars appear to have lots more carbon in their atmospheres than does our sun, and it has been suggested that their peculiar behavior may be a type of carbon poisoning. If so, our sun is immune, but of this we can not be sure. The ice ages of the past *may* have been due to a temperature lapse of this sort.

Most of you remember reading in the papers last December of the discovery of a new star or nova in the constellation of Hercules. This was not really a new star, but an old one, possibly not unlike our sun, that suddenly burst and attained more than 100,000 times its original brilliance. If such a catastrophe were to happen to our sun, the earth would melt and vaporize; the surface of the planet Pluto, despite its distance, would become little short of red-hot. There are certain features connected with the skin eruptions—those flame-like geysers spurting as I mentioned before thousands of miles out into space—that suggest incipient nova activity. I prefer to think of them as safety valves, the method that the sun uses to blow off steam and thus escape the fate of becoming a nova. If this is right, as long as the fiery geysers continue to spout, we have nothing to fear. But if the sun were suddenly to become and remain quiescent, I should begin to worry—not immediately, but after a few thousand years.

I started out to try to answer the question, "Why take the sun for granted?" I fear that my answers are indefinite and perhaps evasive. We see that we can not absolutely rely on the sun. There is a chance, though a small one, that it will explode within our own lifetimes. So confident am I, however, that the sun will continue to shine with sufficient stability to support life for at least a billlion years that I am willing to wager on it—and give any reasonable odds—say one cent to ten thousand dollars. If you want me to increase the time to ten billion years, the odds will have to be lower. The only condition to the wager is that I be allowed to hold the stakes.

MENTAL HEALTH, HAPPINESS AND EFFICIENCY

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MENTAL health might be defined as our mental condition at any given time. There are many degrees of mental health, ranging from the normal, well-balanced attitude to that of worry, anxiety and fear. When we speak of this

last condition, or conditions, we infer that the mental health is more or less impaired, not to the extent of insanity, but to the extent that the individual is handicapped by his innermost feelings and in his effort to be productive at whatever work occupies his time. It is futile or useless for the physician to say to a person in this state, "Do not worry. Everything will be all right." This is scant help in the relief of mental misery and suffering. The problem has deeper significance. The condition arises from within the mind and must be corrected from within the mind. It is not the outward symptoms that should command our attention, but rather the underlying causes producing these symptoms, and only when one has determined by careful analysis what motivates these symptoms can they be helped, and then only by the skilful application of special treatment.

In studying these individuals we find many who are of a particularly sensitive make-up, and there may exist feelings of inferiority without proper reason. They have allowed undesirable habits of thought to dominate their minds. In these cases it is necessary for the individuals to make an inventory of their lives and to evaluate properly their achievements, as so often they only see their failures. We should develop a philosophy of life which will enable us to have a proper perception of our achievements and to learn not to be overwhelmed by disappointments that are an inevitable part of life. There is a second group, particularly in this period of depression, where the anxiety is directly dependent upon economic, social and other troublesome situations over which we have no control. These are due to external circumstances and, of necessity, the correction will have to be of a material nature.

The description thus far relates to the development of the so-called nervous breakdown, and this condition, if allowed to persist, may become a serious mental disorder. The problem of mental diseases is one which touches nearly every person directly or indirectly. If we are so fortunate as not to have a loved one in a mental hospital, at best we are sharing the burden of caring for the insane. Records would indicate that of all hospital beds 50 per cent. are devoted to the care of the mentally ill. The community has met the situation by improving hospitals for the care of the insane. Briefly, we might contrast the custodial institutions of fifty years ago with the bright, sanitary, progressive state hospitals of to-day, where a patient is received with the determination to provide effective treatment, to plan for improvement and cure and for helpful supervision after the patient has left the institution.

Since the problem is so close to all of us we should be keenly interested in methods of prevention. The prevention of mental disease is just as important as the prevention of physical disease, and our greatest hope lies in developing methods through popular education in the field of mental hygiene. We believe that childhood is the golden age for mental hygiene. It is during the early years when the child is plastic that good habits of thought and behavior can be incorporated. Child guidance clinics have now been established in nearly all large cities to aid parents in dealing with the problems of their children. Professional advice for the nervous or problem child will pay big dividends later in life and properly prepare him to meet the difficulties of adolescence. It is in adolescence that the larger proportion of mental diseases develop. Boys and girls of high-school age, who show tendencies to be seclusive, unfriendly and with a pronounced lack of interest in their usual mode of living should be given careful attention, as these are often the early signs of a beginning mental illness. If the com-

munity were educated in the detection of early symptoms we might spare many parents the grief of learning that this dreaded illness has become thoroughly ingrained and little improvement can be expected. After the period of adolescence the responsibility for our mental health rests with us alone. Maturity does not necessarily make us immune from mental illness, and we must observe continued thought and care toward the preservation of mental health.

Particularly, later on in life when there is a decline involving the mental and physical powers of the individual must one exercise vigilance and often effect adjustments. There is a tendency at this time to look back on life, to emphasize mistakes, to minimize successes and to look ahead to the future only with dread. This mental attitude is intensified when these people find themselves beset with physical infirmities and with the realization that they have lost their active memories and powers of concentration. Mental hygiene has two good suggestions here. First, fixation on the physical symptoms must be avoided, lest from a few real symptoms there develop a multitude of much more incapacitating ones. Second, the mental activity of these persons must be continued as usual. By keeping young in interests and in mind and by directing attention toward the use of their mental functions they will be stimulated through their own activity to feel that life still holds much in store.

The goal of the human mind is to direct the body. An unhealthy, poorly balanced mind will not lead to achievement, happiness or efficiency. Only those who can view life's ups and downs with equanimity, maintaining a calm and clear outlook on life, can reach happiness. It is generally agreed that it is the person with a happy mind who is most productive. How can we produce our best when we allow ourselves to be ruffled by intensities of feeling all out of proportion to the causes? True happiness comes from within ourselves, from our own mental attitude, rather than from external conditions.

It is well known that unwarranted worry is one of the most dangerous agents in upsetting mental equilibrium. This fact can not be stressed enough because Americans as a people are prone to worry. It is worrying over one's work that is usually the cause of mental upsets and nervous breakdowns rather than the actual physical effort exerted. Worry is destructive to happiness and invariably impairs efficiency.

Edward Everett Hale has expressed in these words excellent advice along these lines. We should never attempt to bear more than one kind of trouble at once. Some people bear three kinds—all they have had, all they have now and all they expect to have. Within that statement is set forth the essence of mental hygiene. If we could only keep these words before us constantly our days would be more serene, our nights more restful, and our production would reach its fullest extent with happiness and efficiency.

DEMONSTRATION OF DIFFERENCES BETWEEN PEOPLE IN THE SENSE OF SMELL

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"ARE Freesias fragrant? Some say 'yes'; many say 'no,'" was the main label on an exhibit at the International Flower Show which was held this last March in New York City's Grand Central Palace. On a table between two vases of flowers a placard was more specific in its questions and read: "Can you smell these flowers? If so, is the odor weak, medium or strong and do you like it?" Other placards requested visitors to register their reactions to the flowers on the voting machine with the help of the attendant. It was stated that the records would assist in a study of the sense of smell and be of value to science.

The response to the labels was greater than had been anticipated. Although the exhibit was on the third floor, which was less crowded than the floors lower down, a total of over 8,400 registered their votes regarding the odor of two flowers, or a total of over 16,800 votes on floral odors. During the rush hours people were often two and three deep in front of the table which held the flowers, and many left before reporting their vote to the attendant at the voting machine or even before trying the flowers, which were inaccessible because of people ahead of them. The original plan had been to allow each person who smelled of the flowers to register his reaction on the voting machine without aid, as had been the method employed in similar demonstration tests of taste.[1] To this end appropriate labels were pasted over the levers on the machine. The first classification was in regard to strength of the odor. "If there is no odor," "If the odor is weak," "If the odor is medium" and "If the odor is strong," each of these captions had underneath it the direction "vote below." Arrows pointed to the subdivisions, indicating the attractiveness of the odor to those who could smell it. Thus the ultimate lever pulled down would be one of the following: "no odor," "weak and pleasant," "weak and indifferent," "weak and unpleasant"; "medium and pleasant," "medium and indifferent," "medium and unpleasant" or one of the three subdivisions under strong. With the numbers involved, individual voting was soon found to be impractical. The system ultimately adopted was to have at least two attendants always on duty throughout the exhibit.[2] The writer was present during at least part of each of the six days that the flower show was open and took his turn in acting as attendant. The two flowers exhibited each day had contrasting colors, and the "A" flower, which was furthest from the machine, was chosen as having a relatively weak odor to most people, while the "B" flower was selected as being relatively strong. One attendant stood by the "A" flower and explained the purpose of the test and also prepared the visitors for the replies to be given to the atten-

[1] A. F. Blakeslee and A. L. Fox, *Jour. Hered.*, 23: 97–107, 1932; A. F. Blakeslee, *Science*, 81: 504–507, 1935.

[2] The following, at one time or another connected directly or indirectly with the Department of Genetics, took part as attendants: Mr. and Mrs. A. G. Avery, Mrs. A. F. Blakeslee, Mrs. H. R. Brindle, Mrs. E. P. Burtch, Dr. J. L. Cartledge, Miss Helen Houghtaling, Mr. M. J. Murray, Miss Miriam North, Miss Sophia Satina, Miss Lilias Shepherd, Miss Jennie Schultz.

dant at the voting machine. Each was asked to smell of the "A" flower first and say if it had any odor. If an odor was perceived it was to be described as to its strength as weak, medium or strong and also as to its attractiveness as pleasant, indifferent or unpleasant. The visitor was asked then to smell the "B" flower and report his reactions regarding both flowers to the attendant who manipulated the voting machine. Some confusion and loss of votes necessarily resulted from visitors coming from both sides, but the best that could be done without controlled traffic was to make frequent announcements that the "A" flower was to be smelled first. When the system worked well the attendant at the machine could register votes on the pair of flowers at a rate of between two and three a minute.

As a demonstration of the differences between people in their olfactory reactions, the exhibit appeared to be a success, if one can judge from the frequent expressions of surprise when a companion reported what seemed to be an impossible reaction. The "A" flower might be strong to one and weak to another or even without odor, but when the two came to the "B" flower their reactions might be completely reversed. In attractiveness of the odor there was no less divergence of opinion. What was described by one as a delicious perfume might be characterized by the next as an intolerable stench. All the possible combinations of reactions were registered for each kind of flower by at least a few persons with the exception that no votes were recorded "strong and indifferent" for the Apotheose Freesia. The machine was not adjusted so that it could be possible to tell from the records how the same person reacted to both the "A" and the "B" flowers. It was observed not infrequently, however, that a person would call the "A" flower strong and the "B" flower weak or even entirely without odor, although in so doing he was registering reactions opposed to the majority of smellers.

Our selection for each day's test of a pair of flowers with contrasting weak and strong odors was based on previous tests with a sufficient number of persons to make reasonably sure that the majority would find the "A" flower weak and the "B" flower relatively strong.

The summary of the reactions as recorded on the voting machine will be discussed in more detail later. It may not be amiss to give first some of the more general impressions noted by those of us who acted as attendants. The exhibit had much in the way of interest to a student of human reactions in ways that could not be recorded on the machine. Some of this material related to differences in the sense of smell, but much involved differences in general behavior or attitudes of mind.

It was anticipated that there might be some who would make false reports in the way of a prank on the investigation, but their number must have been too small to have had any material effect upon the records.

All the attendants were impressed with the evident interest and sincerity of those taking the tests. Most subjects appeared to make a serious attempt to report accurately the reactions experienced, although some had difficulty in self-analysis. There was not an unnatural tendency to grade the strength of one kind of flower in terms of the other, and the remark would often be made that the "B" flower was stronger than the "A." In such cases the request was made to state the strength of odor of each kind of flower as if it had been smelled by itself and to make the comparison with one's general idea of what would be called a weak, medium or strong odor. If the subject seemed to be in doubt whether to call a flower pleasant, indifferent or unpleasant, he was asked if he liked the odor, disliked it or just didn't care. He was encouraged to

classify the odor as indifferent if pleasant and unpleasant elements were found in the odor which seemed to about equally balance, as was often the case.

It was of considerable interest to note how much people differed in ways aside from their reactions to the odors of the flowers. The idea of testing their senses seemed to appeal to most visitors and they voted with evident pleasure without need of urging. Many brought their friends after voting themselves and a considerable number took the tests again on later days when new varieties were exhibited. Some, however, seemed disinclined to take part, perhaps from fear of showing their inability to detect the odors if they announced their reactions. We had the impression that proportionately more men than women were thus timid at the thought of taking the test. A considerable number of the men who actually voted did so at the invitation of their wives. It was of amusement to the onlookers when members of a family failed to agree on the odors. That they were doing something that would aid science was a satisfaction to some, and a mother was overheard insisting that a reluctant daughter report her reactions to the attendant because it would help science and science ought to be encouraged. A young lady of modern appearance, however, was heard to say that she didn't want to help science, science had never helped her. She had evidently been helped, but perhaps it was art rather than science that had had the most influence.

Some few were opposed to the tests on general principles. They said they were unfair for various reasons and just wouldn't show anything anyway. One woman, for example, before trying the flowers insisted that the whole affair was foolish. "Everybody knows that Freesias have a lovely odor and to ask if Freesias are fragrant is a silly question." It was suggested that she try the two varieties on the table herself and notice for a while how others voted. She started with the "A" flower and turned on us indignantly, "There is something the matter with these flowers, they don't smell at all! You have done something to them." She was assured that they had not been doctored in any way. As she put her nose down among the "B" flowers, her features relaxed and with a smile she exclaimed "A perfectly heavenly odor." While she waited watching the others, a man approached the "A" flowers which she had been unable to smell and called them strong. Upon smelling the "B" flowers (Leucocoryne) which the woman had called heavenly, the man's features hardened and he turned to the attendant almost with anger and said, "Lady, these stink, they stink like h—." The objecting woman's face flushed and she left the group without further objections. Similar situations occurred from time to time in which some one made the unexpected discovery that people really are different in their smell reactions, but none was more dramatic than the one described.

A number of psychologists, amateurs as well as professionals, pointed out factors which would prevent the tests giving reliable results. In all such cases we were able to enumerate more factors than they had mentioned which would render the results difficult of interpretation. We explained that the tests were to be considered more in the nature of a rough survey than as an adequately controlled experiment. The exhibit was modestly labeled merely a demonstration and appeared to be living up to its label. We, as well as the visitors, were learning things we had not known before and we hoped the records might turn out to have some scientific value as a by-product.

To some there was doubt as to the object of the tests and a few, mostly among the men, were even suspicious of some kind of a "racket." A very common question was, "What are you try-

ing to prove?" The answer generally given was that we were not trying to *prove* anything, but rather trying to *find out,* which was the attitude of scientific experiment. This reply was not entirely satisfactory, and one man voiced his doubts by saying, "What is the joker in this game anyway?" Several women thought the exhibit was an advertisement scheme to sell flowers and wanted to buy some. One man, after having his vote registered, held out his hand and said, "Don't I get my fortune, or something?"

Regarding their attitudes toward their own sensations, there appeared to be two main classes of people. There were those who made their own decisions as to how the odor should be described and could not understand how anybody could think otherwise. There were also those who considered the tests in the nature of an examination in which they tried to give the correct answers; they appeared to seek an authority outside of themselves. Of those who looked to themselves for sole authority there were many examples. If others found an odor where no odor could be detected by a person in this class the others were often believed to be laboring under a hallucination. A negative reactor to both the "A" and "B" flowers shifted the blame from his own shoulders with the following words: "You can't smell these flowers so long after they are cut; but the trouble is the public don't know it. They just fool themselves." One woman who could not smell either of the two Freesias exhibited said that the Freesias had lost their fragrance through hybridization. She had a very keen sense of smell, she said; in driving through Connecticut she could smell tobacco from the growing plants long before the fields were in sight and could detect sewer gas when no one else could, not even the plumbers who were looking for the leak. Therefore, she said, the other people at the show just imagined they could smell the flowers and were actually telling us lies, because in reality the Freesias did not have any odor.

A frequent and somewhat more generous explanation was the influence of some factor such as a cold in the head which had rendered the patient's olfactory organs temporarily less acute than normally. Other people who failed to detect odors that appeared perfectly obvious to most were said also to have something the matter with them or to be abnormal. This inability of others was often attributed to their use of tobacco. "Too many cigarettes are why so many men can't smell the flowers and the women are getting just as bad now," was a typical explanation.

Some who failed to detect an odor said that those who smelled it got their odor, not from the flowers on our table, but from the general Freesia odor in the air. Others claimed that the Freesia odor in the room prevented them from smelling the individual bunch in the exhibit. This may have been true in some cases, since banks of Freesias were on exhibition not far from our table. Many experienced the phenomenon of smell fatigue, since they detected the odor at first but lost it upon prolonged smelling. Those taking the tests were asked, therefore, to get their reactions from a few sniffs only.

The possibility of olfactory fatigue led us to put the two vases of flowers at some distance apart on the table and to request the visitors to smell of the "A" or weak flower first. Before this was done, some thought it made a difference in detecting an odor which flower they smelled of first. Perhaps also connected with fatigue was the fact that several persons said they could smell the odor a little way off but not near to. Some called this odor away from the flower the "echo" odor.

Some thought our Freesias must be dead because "they always smelled Freesias," but couldn't smell these.

Some who got weak or no odor thought the flowers were "smelled out," *i.e.*, that repeated smelling destroyed or used up the fragrance.

Environmental factors do have a marked influence upon the sense of smell, much more so apparently than upon the sense of taste, and some of the numerous explanations proffered by certain persons for their poor showing in the tests may be reasonable. It seemed strange, however, how seldom visitors appeared to realize that the difference observed in their reactions to odors was probably, in part at least, attributable to innate differences in individual constitution. This is clearly the case with the sense of taste. Others, as well as the writer, have shown that differences in taste acuity are inherited.

Of those who were not quite sure of the correctness of their reactions and appeared to want an authority outside of themselves to say if they were right, there were numerous examples. Many upon hearing the purpose of the test explained would say, "After I smell will you tell me the right answer?" "Was that the right answer?" or some similar question was the most frequent remark addressed to the one who manipulated the voting machine. To one young lady who asked the common question "Did I vote right?" the writer replied, "Yes, you voted exactly right." Smiles came to the face of the questioner, she had achieved success. The next person voted the exact opposite, and she also was assured she had voted right. A look of surprise came over the face of the first questioner. "But, Professor, she voted different. We both can't be right." Each one was right, she was told, because each one alone could tell what her own reactions are. "But, Professor, how do they smell to you?" To her mind apparently the professor knew the answer but was holding it back from her, as professors have a way of doing for some unknown pedagogical reason.

Some of the seekers for authority looked for it not in single individuals, but from their training in a democracy seemed to think that the majority must be right. Instead of appealing to the attendant with the question, "How should they smell?" they would want to know how the majority voted, apparently with the desire of being on the winning side.

The desire to relate their own reactions to those of the majority was responsible no doubt for part of the interest in the records of previous days' voting which was posted near the exhibit. Many, however, appeared interested in the tests as an experiment entirely aside from their own part in it, and the question was frequently asked as to when and where the results would be published.

One's reactions to odors are much more influenced by associations of one kind or another than is generally realized. Associations may be responsible for one's finding an odor pleasant which is highly objectionable to most people as well as finding another odor unpleasant which most think of as a pleasing fragrance. A man who was asked whether the odor was pleasant or unpleasant replied: "Oh, I sell perfumes. They're all the same to me." The writer finds he has a similar reaction in that he is unable to call any odor unpleasant with which he is experimenting. His interest is in the experiment, and the odor is a part of a pleasurable experience.

Associations appeared to have an influence also upon one's estimate of the strength of odor. The beauty of the flowers made a strong appeal, especially to the women, and may have raised a presumption in their favor when the question was raised whether their odor was pleasant or unpleasant. It was sometimes difficult to get people to consider the odor apart from the appearance of the flowers. "No, I don't like the

pink ones; never have liked that color," was the remark of one young woman. "But the odor, do you like it?" she was asked. "No, I don't like pink," and she left without giving us an opportunity to record her olfactory reactions to the Freesias which had the misfortune to be born pink. Preconceived ideas as to what ought to be may have had influence at times on the reactions reported. Frequently visitors did not want to admit that they could not smell the odor of the flowers but would often do so when they were told that on the first day over half the people could not smell one of the flowers on exhibit. How others voted had some influence apparently on succeeding votes. Often the second of a pair would say, "My vote is just the same as what the first one gave." When we replied that we had to record the votes for each one separately and had no place to vote ditto, the reaction finally reported would generally not be a repetition of the first. Many upon reading the sign "Are Freesias fragrant?" would exclaim "Why, of course they are," even before trying to smell them. Some would approach the flowers with the remark, "Oh, yes, colored flowers are always fragrant." Others would say just the opposite. Most who commented on the relation between color and odor claimed that the white flowers are far superior in odor, although a few said that white ones are weaker. Color of the flowers or the varietal names may have had some influence upon the description of their odor which many volunteered. The orange-colored Freesia, which carried the varietal name of Tangerine, perhaps would not have had its odor described so frequently as like oranges and tangerines if it had had a white flower and been called by a less suggestive name.

It was probably due to association rather than to an exceptionally acute sense of smell that a woman reported to an attendant that she was capable of long distance smelling. She was absolutely sure she could smell over the telephone. There was a man who was a great friend of hers, who often smoked a very strong pipe and several times when she called him on the phone as soon as he said "hello" she could get this very strong tobacco odor. "You just see if this isn't something I have discovered as you go on with your investigating." This was not the only instance of the kind. Another woman in passing the exhibit was overheard to tell her companion that she could smell over the telephone.

Visitors were found to be willing not only to answer the simple questions put to them for purposes of record, but also volunteered information not asked for. It was especially the women who desired to describe the odor of the flowers in terms of something else. The difficulty that any one person has in classifying odors is well known. The difficulties are not lessened when many people attempt to describe an odor. Although individually many people seemed able on different days to distinguish the "A" from the "B" Freesias by quality as well as by strength of odor, it would be impossible from any single description to know which Freesia was being referred to.

It may be of interest to give from our notes some of the characterizations of the odor of the "Tangerine" Freesia exhibited the last two days of the show. Among the descriptive terms heard a number of times are the following: peppery, pungent, spicy, bitter, woodsy, grasslike and medicinal. The odor was frequently compared with that of oranges, tangerines or citrus fruits in general, dandelions, orange blossoms, honey, hay and soap. The odor was also said to resemble that of lavender, buttercups, verbenas, marsh marigolds, wood violets, saffron, crocus, goldenrod, orange marmalade, tea, sandalwood, peppermint, Japanese lacquer, paprika, aromatic spirits of ammonia and skunk

cabbage (but pleasant). Perhaps equivalent to the adjective "woodsie" is the description of the odor as fresh, like spring, or cool, like wet sawdust. One visitor found a strong association with his youth and said, "It smells like a straw bed I slept in when a boy—the kind they used to have in Missouri."

To some the odor was of a character that could hardly be classed with ordinary floral odors. The following remarks were overheard: "It has no odor, but gives a sensation of intoxication." "You can't smell it; you just feel it." "No odor, just an out-doors smell."

The "B" flower on the last two days was not a Freesia but an equally attractive flower called the "Glory of the Sun" (Leucocoryne ixioides). To the writer it had a compound odor with two distinct elements. One resembled the fragrance of heliotrope and was pleasant, the other resembled the odor of fleshy fungi and was of a type that would be called unpleasant by most people. The writer's associations established by working with fungi prevented his finding this element in the odor unpleasant. To those who liked the odor of the Leucocoryne, it smelled most frequently like heliotrope, though it was also compared to the odor of hyacinth, narcissus and mignonette. The other element was probably uppermost in the minds of those who described the odor in the following terms: queer swampy odor, musty, like decaying mushrooms, like yeast, purple trillium, sour, like blue sour sapwood, carbolic acid, a sanitarium, bitter almonds, skunk cabbage, anise and licorice cake. Some used in their descriptions some of the same terms applied to the Tangerine Freesia, such as like dandelion, honey and woods in spring time. Some detected only one of the two odors which were distinct to the writer, but others could distinguish both. These latter often reacted differently to the two components, some finding the first, others the second the stronger. Many found a pleasant and unpleasant component about equally distinct and had difficulty in deciding whether to call the odor of the flower as a whole pleasant or unpleasant.

Visitors often were not content to discuss merely the odors of the flowers exhibited, but in addition related interesting experiences they had had with other odors. These conversations, however, were by no means confined to the sense of smell, and at times the writer felt in a way as if he were officiating at a confessional, since he was told much that is not generally related. All that was told emphasized, often in unsuspected ways, the great diversity between people in their sensory reactions. There are not a negligible number, for example, who can recognize other people by odor in the same way in which dogs can distinguish different individuals by scent alone. This power is more frequent in children, but is often retained into adult life. There is a social taboo against speaking of personal odors, and this extreme acuity of smell is generally concealed by its possessor.

At the opposite extreme were the surprisingly large number of people who reported that they had lost the sense of smell. To some the loss had come gradually, to others rather suddenly. Some could connect it with nasal disease, such as a cold or sinus trouble or to an operation; others could offer no explanation. Most were questioned regarding whether after the loss of smell they could still detect flavors which are generally classified as odors. The majority thought they had not entirely lost the perception of flavors. Since it is difficult for a person clearly to separate all the sensations experienced in the mouth it is possible that in such cases only the primary tastes for bitter, sour, sweet and salty had been retained. The question has considerable interest in interpreting sensations perceived by way of mouth and nose, respectively, but can be settled only

by tests of individual cases. Some of the instances of loss of smell (called anosmia) had family histories which suggested that hereditary factors were involved. One woman had lost her smell when she was about 25 years old. She had one anosmic brother who lost his smell when he was between 30 and 40, in addition to six normal brothers and one normal sister. Her mother was anosmic and was highly sensitive to flax seed and her maternal grandfather suffered from hay fever.

Those just discussed had apparently lost their sense of smell permanently, but others reported that the loss which had come from a cold, an operation or from unknown causes had been of shorter or longer duration but that the ability to smell had ultimately returned. There was one person who said he had never been able to detect odors, and cases of total anosmia from birth are reported in the literature.

From the foregoing discussions it is evident that people differ in ways that could not be recorded on our voting machine. Even though the records give an idea of the range of variation in acuteness of smell they were in many respects difficult to interpret, since the environmental conditions of the tests could not be controlled. The odor of the flowers probably varied, becoming fainter during the day, as was indicated by the votes recorded hourly which showed an increasing number of people who voted no odor toward the end of the day. Individual differences were noticed between different flowers in the cluster. It is not unlikely that differences in such factors as temperature, relative humidity and barometric pressure of the air on different days may have had an influence upon the production of odors in the flowers or upon the smelling abilities of the visitors. The mixture of floral odors in the building no doubt conflicted with the tests, but more disturbing were the synthetic chemicals sprayed upon visitors who ventured too near a booth labelled "Perfumery" which was located on the same floor. All these environmental factors tended in a measure to average out so that the records on a given day are probably fairly comparable. There were other factors, however, associated with the personalities of the different attendants. The way one voted was influenced by the way in which the test was explained and the questions asked. With a little encouragement, such as a statement of the relatively large number who could detect no odor on an earlier day, the number who voted "no odor" could be increased.

Despite all the influences that we feared would detract from the reliability of the tests, the summary of the votes shown in Table 1 contains evidence that the tests give a fair measure of the relative strengths of different floral odors and of the relative abilities of people to detect these odors. All the flowers in the table, except the white No. 5, had been used in a lecture demonstration a year previous and the strength and attractiveness of their odors at that time were in the same relative order as at the flower show. An indication that the method can detect differences in strength of odor in the same varieties may be seen from the records of the Freesia varieties Maryon and Golden Daffodil on Monday in comparison with those of the same varieties on Tuesday and Thursday. On Monday the odor for both was decidedly weaker as shown especially by the relative number who voted "no odor." This great difference between other days puzzled us until we learned that the flowers on Monday had been kept 24 hours longer after picking than on other days. The grower's schedule for week days involved cutting the flowers at about 11 A.M. and keeping them in a cool head house till about 5 P.M., when they were packed in boxes ready for trucks which picked them up between midnight and 2 A.M. and deliv-

ered them to the wholesale dealers between 3 and 5 A.M. They stayed in the boxes till the wholesaler took them out about 7 in the morning. An attendant brought them to the flower show between 9 and 10 o'clock, when the show opened. The flowers for Monday, however, had been cut on Saturday morning and apparently had lost some of their fragrance by longer standing.

Let us first consider the information in Table 1 from the standpoint of the grower, Mr. C. J. Van Bourgondien, of Babylon, Long Island, who had kindly provided the Freesias used in this and earlier tests. The interest here lies in discovering the relative strength and attractiveness of the odors of the different varieties. No single nose could be used as an adequate standard of how the

TABLE 1

	Flower "A" Number	Flower "A" Per cent.	Flower "B" Per cent.	Flower "B" Number
	Monday			
	Freesia var. Maryon (Blue) 990 votes.		Freesia var. Golden Daffodil (Yellow) 987 votes.	
No odor	508	51.31	10.44	103
Weak	423	87.76	31.79	281
Medium	49	10.17	43.67	386
Strong	10	2.07	24.55	217
Pleasant	359	74.48	87.90	777
Indifferent	100	20.75	5.88	52
Unpleasant	23	4.77	6.22	55
	Tuesday and Thursday			
	Freesia var. Maryon (Blue) 2,837 votes.		Freesia var. Golden Daffodil (Yellow) 2,831 votes.	
No odor	952	33.56	5.26	149
Weak	1562	82.86	19.57	525
Medium	270	14.32	39.78	1067
Strong	53	2.81	40.64	1090
Pleasant	1466	77.77	85.94	2305
Indifferent	311	16.50	6.97	187
Unpleasant	108	5.73	7.08	190
	Wednesday			
	Freesia var. Apotheose (Pink) 1,734 votes.		Freesia var. Van Bourgondien No. 5 (White) 1,728 votes.	
	529	30.51	6.94	120
	990	82.16	32.59	524
	180	14.94	43.28	696
	35	2.90	24.13	388
	885	73.44	84.82	1364
	249	20.66	9.76	157
	71	5.89	5.41	87
	Friday and Saturday			
	Freesia var. Tangerine (Orange) 2,859 votes.		Leucocoryne ixioides "Glory of the Sun" (Blue) 2,864 votes.	
	478	16.72	1.15	33
	1289	54.14	18.72	530
	736	30.91	38.33	1085
	356	14.95	42.95	1216
	1431	60.10	59.94	1697
	526	22.09	10.84	307
	424	17.81	29.22	827

Wide World Photo

A. G. AVERY REGISTERING A VISITOR'S REACTION TO ONE OF THE FREESIAS.

majority react to a given odor. The grower, for example, believed his White No. 5 to have the strongest and best odor of any Freesia and was greatly surprised therefore to see that in the judgment of the public his variety "Golden Daffodil" was stronger. This latter variety received slightly fewer votes for "no odor," had significantly fewer votes for weak (20 per cent. against 33 per cent.) and considerably more for strong (41 per cent. against 24 per cent.). In attractiveness of odor there was probably no significant difference, although a slightly higher percentage called the odor of the Golden Daffodil pleasant. In strength of odor, the Maryon may be listed as the weakest, with Apotheose slightly stronger and slightly less pleasant. Tangerine was intermediate in strength of odor, but the odor was unpleasant to a higher proportion of people than was the case with any other Freesia. Among varieties with strong odors, the Golden Daffodil was strongest with Van Bourgondien's White No. 5 next in strength.

The odor of the Leucocoryne was stronger than that of the Freesias, and to a large proportion of the visitors was distinctly unpleasant. As explained earlier, the odor had two distinct components to which people reacted differently. It should be pointed out that the reactions recorded refer to odors smelled when near the flowers. If the odors had been diluted by distance, the reactions would have been different.

The information in Table 1 furnishes probably the most extensive data so far assembled regarding the judgment of the public as to the odor of flowers. Whether such information is of commercial value can be determined by those in the trade.

Herbert Studios

VIEW OF THE EXHIBIT SHOWING THE TWO VASES OF FLOWERS WHICH VISITORS WERE REQUESTED TO SMELL AND THE VOTING MACHINE ON WHICH THEIR OLFACTORY REACTIONS WERE RECORDED.

It has been a matter of surprise, however, to learn how little those whose business it is to cater to the taste and odor preferences of the public take into consideration the fact that people differ in their sensory reactions of taste and smell. After reading papers on differences between people in taste and smell reactions, an official of a firm which deals in products whose sale value is determined by their flavor confessed to the writer that he doubted if the concentration of the flavors was a matter which should be determined solely by the vice-president, as apparently had been their custom.

Whether an odor is pleasant or unpleasant is determined both by the nature of the odor and the associations which have become tied up with it and also by its strength. Odors which are too strong are unpleasant, but what is strong to one may be weak to another person. These conclusions are evident from tests with odors much more concentrated than those given off by the flowers in the exhibit. The data in Table 1 are not arranged in a way to show the relationship between attractiveness and strength of odor. The fact that the Tangerine variety was unpleasant to a larger percentage than the stronger "A" Freesias might seem to indicate that in these tests strength of odor had little if any connection with unpleasantness. A different conclusion is reached for the Tangerine and other varieties when the votes are listed to show what proportion of those who called the odor pleasant found it also weak or strong. In this calculation the uncertain records "medium" and "indifferent" were not considered, and the percentages were based on the extremes, weak and strong, pleasant and unpleasant. For the weak or "A" Freesias, of those who called the odor pleasant, 92 per cent. found it weak and 8 per cent. found it strong; whereas of those who called the odor unpleasant, 68 per cent. found it weak and 32 per cent. found it strong. For the strong or "B" Freesias, of those voting pleasant, 40 per cent. voted weak and 60 per cent. voted strong; whereas of those who voted unpleasant, 36 per cent. voted weak and 64 per cent. voted strong. For the Leucocoryne, of those who voted pleasant, 32 per cent. voted weak and 68 per cent. voted strong; whereas of those who voted unpleasant, 21 per cent. voted weak and 79 per cent. voted strong. In all these cases an increase is noted in the proportion of those who find the odor strong as we change from pleasant to unpleasant.

After the first two days, the votes of men and women were recorded separately. Summaries of these records are shown in Table 2 for all the Freesias, grouped together, and for the Leucocoryne. Significant differences are evident in the way in which men and women

TABLE 2
PERCENTAGES IN DIFFERENT CLASSES

	All Freesias Total voting: men, 2,196	women, 6,761	*Leucocoryne* Total voting: men, 786	women, 2,078
	Men	Women	Men	Women
No odor	19.44	17.07	2.03	0.80
Weak	56.88	52.54	17.15	19.01
Medium	27.51	29.29	42.06	37.01
Strong	15.61	18.17	40.80	43.99
Pleasant	67.74	75.09	64.98	57.20
Indifferent	21.42	15.41	10.67	11.01
Unpleasant	10.84	9.50	24.35	31.80

voted, but it is doubtful if this fact indicates any differences in the olfactory acuteness of the two sexes. If one considered records on the Freesias only, one might argue that the differences were connected with the evident greater appeal that flowers make to the feminine mind. Women were therefore more inclined than men to call an odor pleasant which was associated with beautiful flowers. They were more hesitant to say there is no odor, and when they reported

an odor they were more inclined to rate it as strong or at least as medium. It also has been suggested to us that since men as a group are less interested in flowers they were more inclined to tell the truth when they found them without odor. The explanations suggested, although in accord with impressions of attendants at the flower show, can not be applied without modification to all odors, since the differences between the sexes in reaction to the odor of Leucocoryne were in most cases the opposite of what they were for Freesias. A component of the odor of Leucocoryne was unusual for a flower. This unexpected and strange odor may have shocked the women more than it did the men, who are relatively indifferent to how a flower looks or smells, and hence fewer women voted pleasant. We can only conclude that there were differences between men and women in the way in which they reported their reactions to the floral odors, but the cause of these differences is unknown.

The exhibit showed, even under the unfavorable conditions prevailing at the Flower Show, that it is possible by the simple method employed to demonstrate in dramatic manner the fact that people differ widely in their sensory reactions to odors. The records are of value in showing something of how wide these differences are. Of considerable value also was the unanticipated information gleaned from personal conversations with visitors, since it helped to orient the writer in a difficult field and pointed to problems that need investigation. The writer wishes to acknowledge his indebtedness to those who contributed to the success of the exhibit: to Arthur Herrington, secretary of the International Flower Show, who provided space for the exhibit; to Russell F. Griffen, who placed a voting machine at our disposal, and A. R. Bailey, who cared for the installation of the machine at the Flower Show; to C. J. Van Bourgondien, of Babylon, Long Island, who provided the flowers for the demonstration; and to those already named who acted as attendants at the exhibit and took notes of the interesting comments made by visitors whom they tested.

THE PROGRESS OF SCIENCE

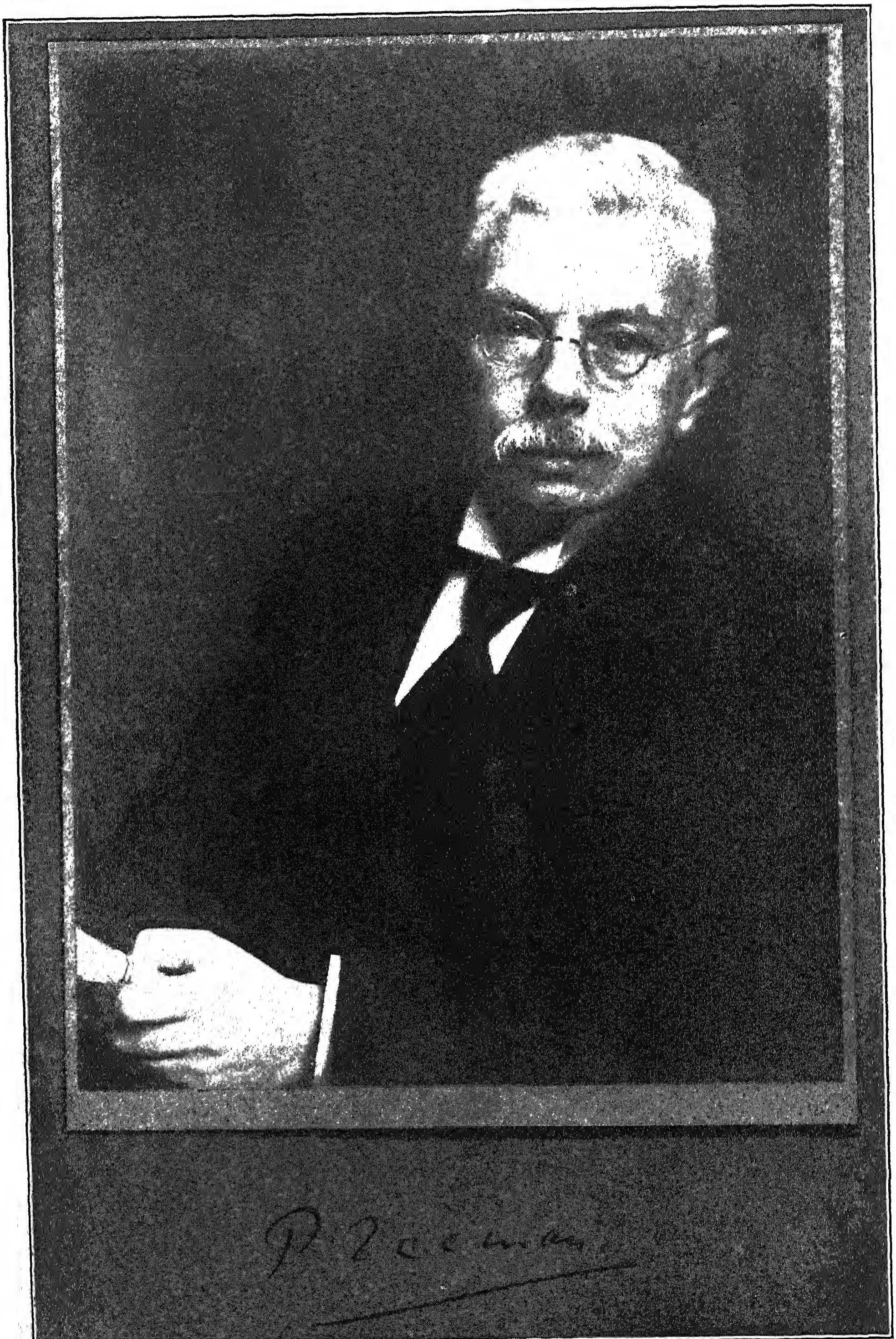
THE SEVENTIETH ANNIVERSARY OF PROFESSOR P. ZEEMAN

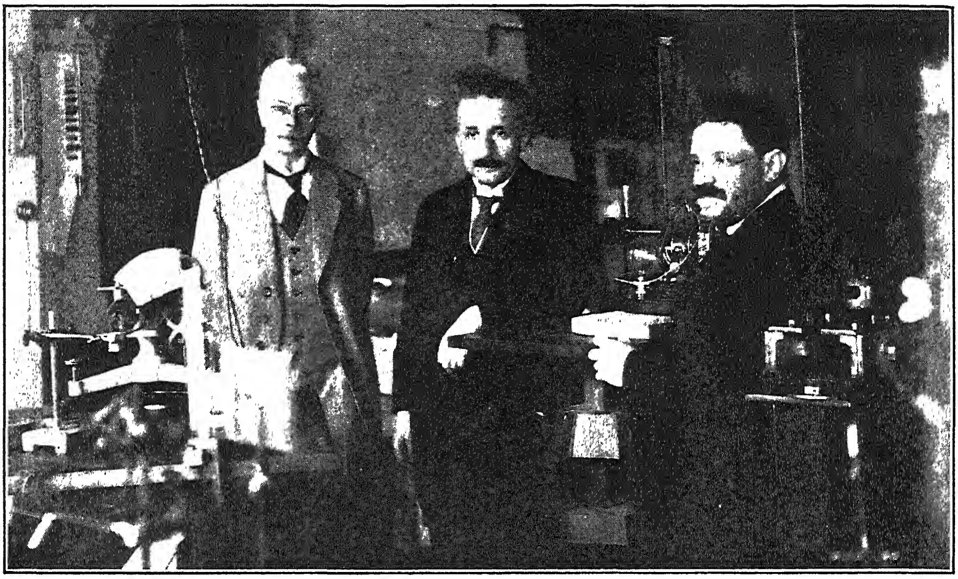
On May 25, 1935, Professor Pieter Zeeman reached his seventieth year, the age for retirement as an active professor at the University of Amsterdam. His friends and admirers throughout the world seized the occasion again to honor the discoverer of the famous "Zeeman effect," the twenty-fifth anniversary of this discovery having provided cause for a similar celebration in 1921. However, it required more than a quarter century for the full significance of this discovery to be realized. In 1921, there was still no systematic and satisfactory interpretation of complex Zeeman effects, but a few years later all became clear and the long hidden mysteries of spectral structures were explained. It is no exaggeration to state that Zeeman effects have disclosed many of the fundamental laws of atomic physics, finally brought law and order of extraordinary beauty and simplicity into the periodic classification of the chemical elements, and that they will always be the most important criteria for the analysis of spectral and atomic structures. These recent successes have greatly increased the appreciation of Zeeman's discovery among physicists the world over, and it becomes easy to understand their eagerness to do him honor. Now they have contributed 51 research papers to a jubilee volume, and donated a fund to be used for a scientific purpose to be indicated by Professor Zeeman himself. Those who are interested to know more about the man who inspires such adoration and international cooperation may read on.

Pieter Zeeman was born at Zonnemaire, Zeeland, in 1865. He studied at the University of Leiden, where he became assistant in physics in 1890, privatdozent in 1894 and lecturer in 1897. He was appointed professor of physics at the University of Amsterdam in 1900 and director of the physical institute in 1908. Zeeman and Lorentz shared the Nobel prize for physics in 1902.

The first attempt to detect a change in the lines of a spectrum when the source was acted on by a magnet appears to have been made by Faraday in 1862. Zeeman repeated this experiment in 1896 and had the good fortune to combine, for the first time, the use of sharp lines, a strong magnetic field and a powerful spectroscope, the three essentials for success. The first observations were made on the yellow lines of sodium, and a distinct widening of the lines was seen when the electromagnet was animated. Professor H. A. Lorentz, the brilliant theoretical physicist, predicted as a consequence of his electron theory that the edges of these widened lines would be polarized. This conclusion was immediately confirmed by Zeeman's experiments, and thus, many years before the electron was isolated, it was demonstrated that negatively charged particles were involved in the emission of spectral lines. Lorentz's theory also predicted that a spectral line observed parallel to the magnetic field would be a doublet of circularly polarized lines; while transverse observation would show a triplet of linearly polarized lines. These predictions were completely verified in 1897 by Zeeman, who thus became the first man to see a fully resolved magnetic pattern of a spectral line. At this point, it first became possible to determine from measurements on spectral lines the value of e/m.

Further investigation revealed, in addition to the simple triplets, many complex types of magnetic splitting. These were called "anomalous," and included the D lines of sodium which, when fully resolved, show 4 and 6 components (observed transversely). In spite of these disturbing anomalies, an underlying simplicity was indicated by the discovery of





ZEEMAN, EINSTEIN AND EHRENFEST

Preston's rule (1899), of Runge's rule (1907) and of the Paschen-Back effect (1912). A complete understanding of the complex Zeeman effect had to await the development of the quantum theory of spectra, suggested by Bohr (1913), but there is no doubt that it hastened this development.

According to the quantum theory, the maze of spectral lines characteristic of a chemical element originates from transitions between spectral terms or atomic energy states having much simpler properties than the lines. Experimental data on magnetic splitting were formally correlated with multiplet structure of spectra by A. Lande (1923), and the theory was soon elaborated to express displacement, polarization and intensity of all magnetic components of any spectral line in terms of quantum numbers associated with the two spectral terms involved. As a result, all the so-called anomalous Zeeman effects which had accumulated during more than a quarter century, but had remained uninterpretable, were suddenly explained, and it was lamented that more data were not available. They revealed simple order in the most complex and apparently chaotic spectra, correlated spectral terms with electron configurations in atomic structure and indicated that all atomic spectra are governed by the same simple but general rules.

Although the Zeeman effect has now been under investigation for nearly 40 years, there is little or no prospect that the field will ever become exhausted. Even now, Zeeman-effect data are entirely lacking for many complex spectra, for practically all spectra beyond the first stage of ionization, and for the infra-red and far ultra-violet. With modern improvements in technique, it is possible and highly desirable to extend the usefulness of this method.

Other fields to which the Zeeman effect has been successfully applied are the problem of hyperfine structure of spectral lines, analysis and interpretation of molecular spectra and the study of sunspot spectra which proved that the sun has magnetic polarity like the earth, and that the law of solar storms is similar to that of terrestrial cyclones.

William F. Meggers

Chief of Spectroscopy Section
National Bureau of Standards

JOHN JAMES RICKARD MACLEOD

JOHN JAMES RICKARD MACLEOD, PHYSIOLOGIST

SEPTEMBER 6, 1876–MARCH 17, 1935

It is not my purpose to write a history of Macleod, but rather an appreciation of the man and that for which he stood. I knew him chiefly in the days before he had become a historic figure as a partner in the discovery of insulin, an achievement which has made a new world for the legions of diabetics, present and future. The foundations for his share in this were laid in the man, in his training and in his environment long before the discovery was made, and it is in this more human side of which I wish to write—of Macleod the man, as his friends knew him, the genial Scotchman, who had turned his versatile and fertile mind with its ever fresh, almost boyish enthusiasm, to medical physiology in all its branches, physical and chemical, extending its roots down into organic and physical chemistry, bearing blossoms and fruits in its applications to the medical problems of health and disease and of healing. It was not an accident that so many of Macleod's disciples went into medical practice, ennobled by what they had learned of him; nor was it accidental that his chief discoveries were in the field of practical medicine. He appreciated the value of fundamental science, but his mind had a turn toward the practical, broadly conceived, and his interest was frankly in the medical rather than in the biological aspect of physiology and in chemical physiology rather than in biochemistry.

In 1903 Macleod was called to Cleveland to succeed G. N. Stewart as professor of physiology at Western Reserve University, and he accepted the call with youthful enthusiasm—he was only twenty-seven at the time, but somehow this youthful enthusiasm never seemed to age. He had graduated in medicine at Aberdeen; worked on purin metabolism at Leipsic, and assisted Leonard Hill in London. His immediate care was for teaching, and he captured the hearts of the students. He was and remained one of them; his lectures were crisp, clear, critical and convincing, his informal discussions inspiring; his laboratory courses practical. Physiology was a series of living, evolving problems generally with obvious practical bearing. Young men were attracted to him and worked as volunteers and as assistants on these problems, chiefly on circulation and respiration, and then on diabetes, which soon became Macleod's dominant research interest, especially when the development of new quantitative methods of blood sugar determination offered the possibility of checking, improving and extending the work of Claude Bernard.

His was a restless spirit; and although he was happy in the very busy life of teaching, research, writing and collaborating in several books, offices in scientific and medical societies, he developed a feeling that he might grow set and rusty by remaining too long in one environment. This made him susceptible to the repeated invitations of Sir Robert Falconer to go to Toronto and to assist in the contemplated reorganization of their medical teaching. He resisted for a time, but eventually succumbed, in 1918. He took his interests with him, and again a group of young workers gathered about him and were inspired by his enthusiasm for working on problems. Among these was Dr. Banting, who had thought out novel approaches for investigating the rôle of the pancreas in diabetes, a subject which still claimed a major share of Macleod's interest. This topic was at that time very much in the foreground; several workers were on the track of actively anti-diabetic extracts of the pancreas, but had failed to make convincing demonstrations. The solution appeared near, but further progress demanded new and fertile ideas, such as those that were in Banting's

mind; and also and equally a wide and intimate knowledge, obtainable only by long personal work in the field, a genuine familiarity with what had been done, and how far it had succeeded and why it had failed; a command of technical methods and their limitations, and a good measure of critical skepticism, to anticipate and to guard against false and premature conclusions, and withal persistent and enthusiastic faith in the feasibility of solving the problem; and finally, the ability to organize the forces to follow up promising leads, to clear away obstacles and to consolidate the success. This wide knowledge and experience of the subject, this judicious combination of enthusiasm and skepticism, this ability to lead, to organize, to inspire, Macleod possessed to a rare degree. I remember discussing the matter with him, when he felt certain that the problem had been solved, but when he was still restraining publication, till every possible doubt and objection had been met in advance. He was full of warm-hearted enthusiasm, tempered with caution. He was convinced that insulin had been discovered, he saw the new life that this opened to the diabetics, the benefits that should not be denied to them, that must not be delayed a moment longer than necessary. He had toiled and planned and toiled to eliminate the delays. He had struggled to save them the cruel disappointment of false hopes; his conscience had driven him in both directions; at last he felt that the sun of certainty was dawning. "Aye," he had tried to raise every objection that he could, together they had tested and met them all, he could think of no more. It was a "go."

The discovery of insulin is an outstanding instance in "team" research, by a partnership of workers where each contributes all his capital of special talents and experience to a common cause. In such a partnership it is generally of little use to inquire "who won the war," it was the partnership that won. It is of little use to argue what might have been the outcome without the partnership. Probably the discovery would not have been made then and there; there would have been delay at least, perhaps failure. The Nobel Prize Committee followed the course of wisdom when in 1922 they divided the prize equally between Macleod and Banting; and these acted generously as well as wisely when they in turn divided it with their junior partners, with Best and with Collip.

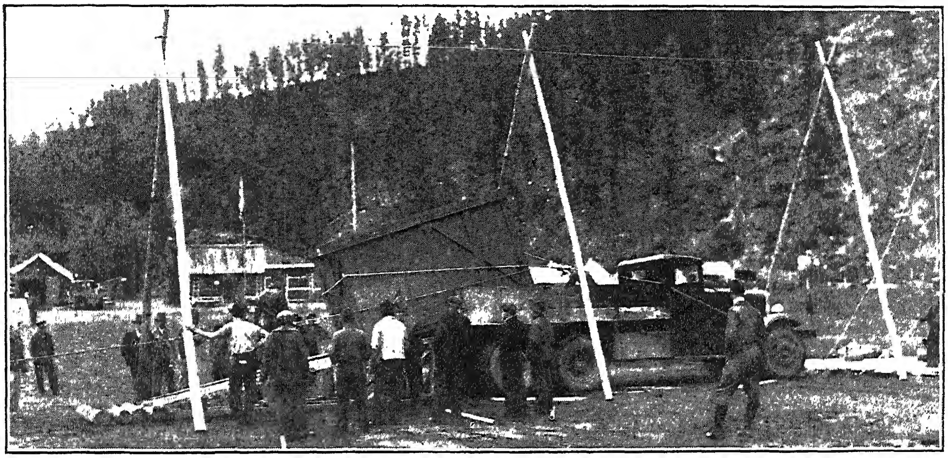
TORALD SOLLMAN
PROFESSOR OF PHARMACOLOGY AND MATERIA MEDICA, WESTERN RESERVE UNIVERSITY SCHOOL OF MEDICINE

A FIELD REPORT ON THE STRATOSPHERE FLIGHT FROM DR. BRIGGS

I AM writing this in camp on June 7 in the cliff-sheltered "bowl" in the Black Hills of South Dakota. Preparations for the 1935 stratosphere flight under the joint sponsorship of the National Geographic Society and the Army Air Corps are rapidly nearing completion. The great balloon is safely stored in its box in the center of the bowl. Over 1,800 cylinders of compressed helium gas are stacked nearby in neat rows awaiting the inflation. The gondola is mounted on a special truck ready to be wheeled under the balloon.

The gondola is of course the center of activity. Its shed is flanked by dark rooms and tents for unpacking and testing the apparatus for the flight—the cosmic ray tent, the spectrographic tent, the tent for ballast and balloon valves. Physicists are busy installing their instruments in the gondola, while balloon riggers are working on top attaching the suspension ropes, the ballast supports, the heavy batteries for operating the instruments and the great parachute for use in an emergency.

The gondola is a veritable floating



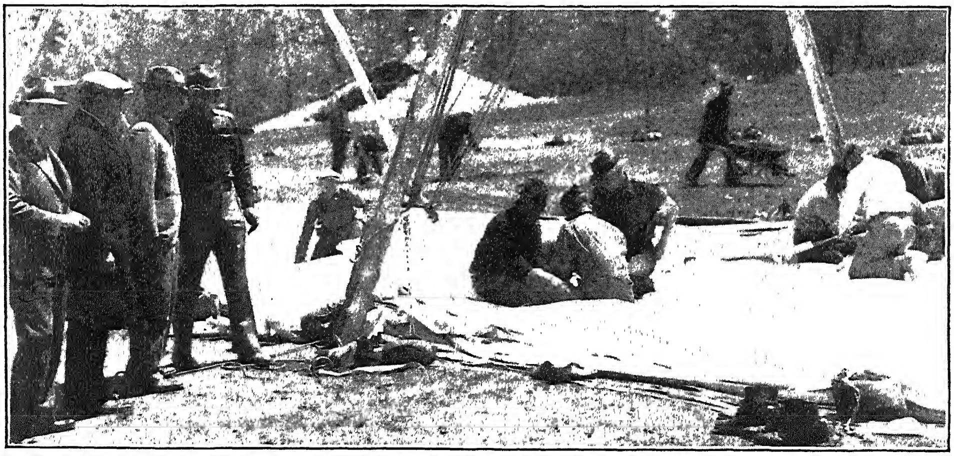
Photograph from National Geographic Society.

UNLOADING THE BALLOON IN THE BLACK HILLS

laboratory. For the study of cosmic rays it carries three electroscopes for measuring intensity at various altitudes, apparatus to count the rays coming in at various angles to the vertical, apparatus to measure the sudden "bursts" of cosmic radiation and a cloud chamber to photograph these bursts. It carries also a sky spectrograph and apparatus for measuring the temperature and pressure of the outside air and the brightness of the sun, earth and sky, together with cameras and broadcasting and navigating instruments. Suspended outside are the ultra-high frequency transmitters, the sun spectrograph and the spore-catching apparatus.

Two days more and the installation will be completed. Then with all apparatus on board the gondola will be rolled out and turned to "swing the compass," just as an ocean liner is turned through a complete circle to find whether or not in all positions the compass truly points to the magnetic north pole.

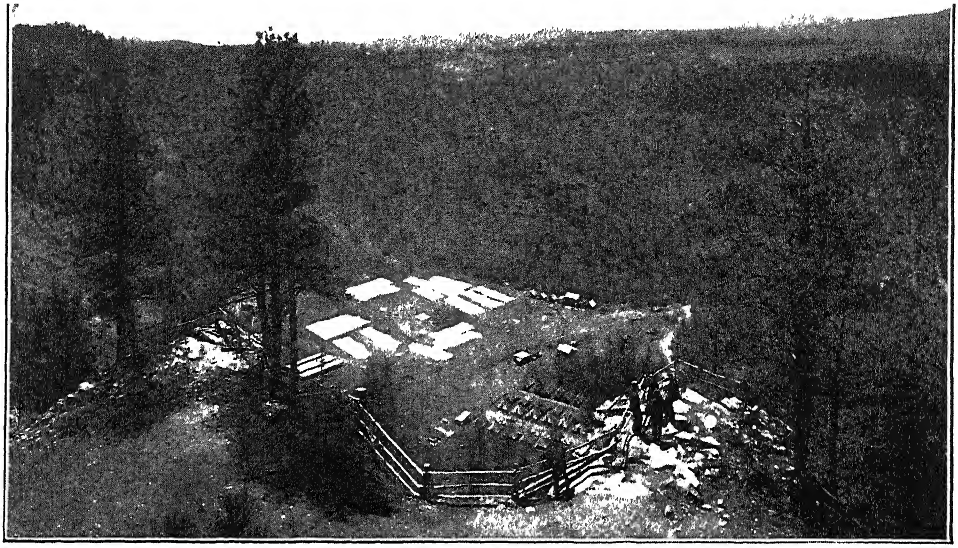
Six thousand pounds of fine lead shot



Photograph from National Geographic Society.

FINAL PREPARATIONS FOR THE STRATOSPHERE FLIGHT

George W. Hutchison, Secretary, Dr. John O. La Gorce, Vice President, and Dr. Gilbert Grosvenor, President, of the National Geographic Society; and Captain Orvil A. Anderson, pilot, observe the attachment of the load ropes to the suspension points of the balloon.



Photograph from National Geographic Society.

AERIAL VIEW OF THE "STRATOCAMP"

in sacks weighing 150 pounds each will be carried as outside ballast. These sacks will be hung from the load ring of the gondola after it is finally placed below the great balloon. Each sack contains a blasting cap electrically connected to a switchboard so arranged that any sack may be opened by simply closing a switch. The heavy batteries are also hung in such a way that they can be dropped, each on its own parachute.

With everything so nearly ready, Captain Stevens and Captain Anderson are giving increased attention to the weather. Four complete weather maps are being prepared at the camp each day from information sent in by wire and radio. Ideal weather for the flight would be a cloudless calm day at the bowl for the take-off and clear skies and low surface winds for 400 miles to the southeast. We have not had suitable weather for the flight since we have been in camp and we are now waiting expectantly.

LYMAN J. BRIGGS

DIRECTOR, NATIONAL BUREAU OF STANDARDS; CHAIRMAN, SCIENTIFIC ADVISORY COMMITTEE OF THE NATIONAL GEOGRAPHIC SOCIETY—ARMY AIR CORPS STRATOSPHERE EXPEDITION

THE CELEBRATION OF THE CHEMICAL INDUSTRIES TERCENTENARY

IN the year 1635 John Winthrop, Jr., launched a chemical industry. The first governor of Connecticut, anxious to see the colonies independent of foreign sources of supply, projected the manufacture of salt, glass, potash, iron, tar, saltpeter, copper, alum, gunpowder and medicines. It is not surprising that most of his ambitious plans never reached fruition. When it is considered that Winthrop flourished during the early days of the phlogiston fantasy, the surprising thing is that he conceived such an elaborate program of chemical manufactures. And when it is realized that he actually started the production of salt, saltpeter and pine-tar, it is apparent that he was an artisan of no mean ability.

At its eighty-ninth meeting, held in New York towards the end of April, the American Chemical Society celebrated the three hundredth anniversary of Winthrop's salt manufactory. Emphasis was placed on the chronological development of our industries, and the growth of chemistry from alchemy was traced. Through a remarkably fortunate circumstance, 270 volumes from Winthrop's library have been preserved, and some fifty of these were exhibited at the Hotel

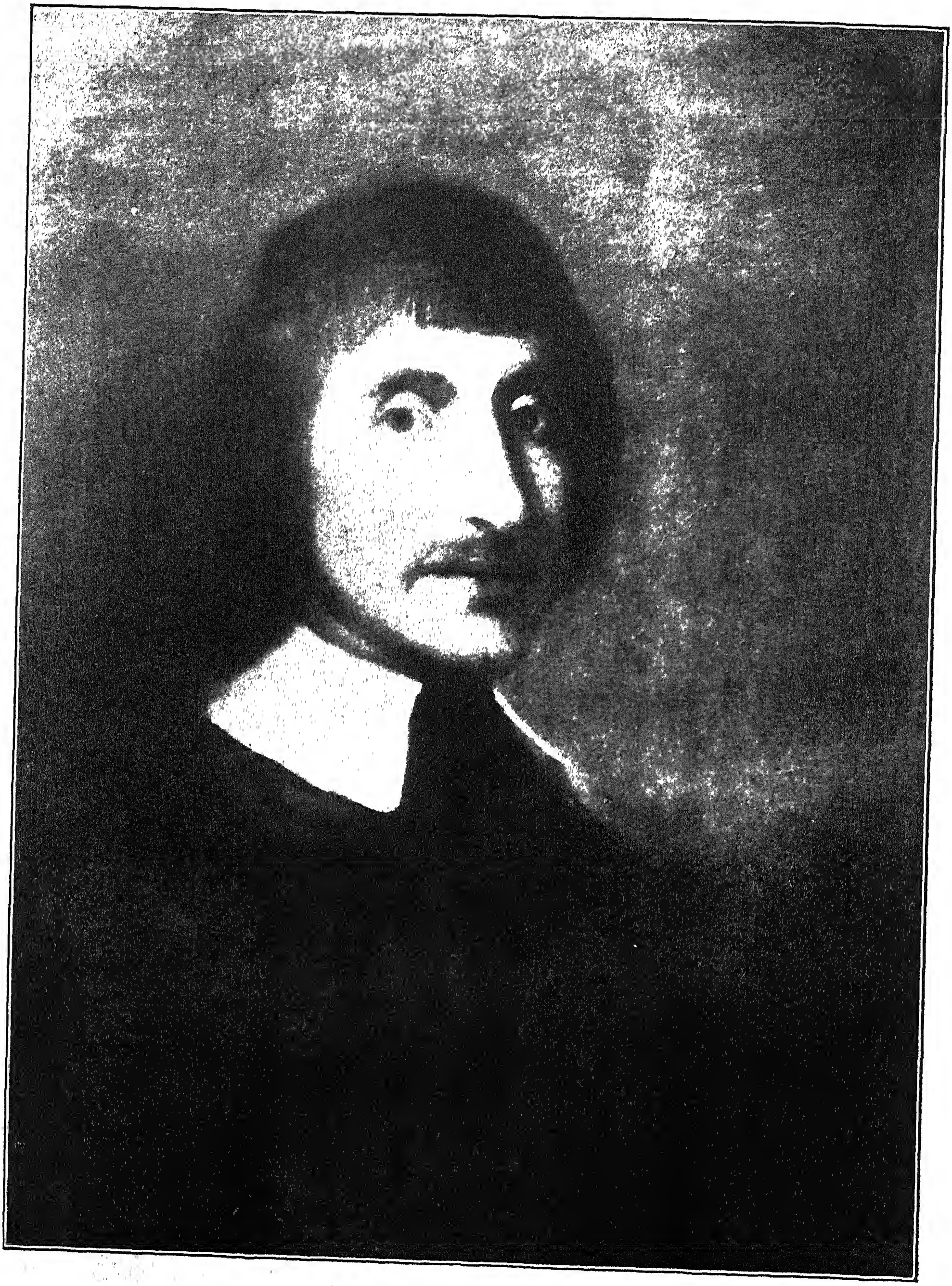
Pennsylvania. Their contents demonstrated graphically the aura of mysticism which surrounded early chemical art.

Attendance at the meeting surpassed all previous records, though not by so wide a margin as had been anticipated. The total registration was 5,105, representing 43 states and 17 foreign countries. Of these New York State contributed 1,697, and New York City 1,087. Of the 588 papers presented, only a few can be noted in this summary; it has been decided to select those which appear to be most significant in projecting the trend of research.

If any event on the program were singled out as being of superior significance, it would be the presentation of the Nichols Medal to Dr. Julius A. Nieuwland, of Notre Dame University. It is well known that he has worked for three decades on the chemistry of acetylene and its derivatives. One vast commercial application of these researches is Duprene. The peculiar superiority of this synthetic rubber, as Dr. Nieuwland pointed out in his address, lies in the fact that it contains chlorine in addition to carbon and hydrogen. It is not an imitation of nature's product, but it is better. It is non-inflammable and is more resistant to heat, oils and abrasives than natural rubber. The raw materials are limestone, coke, water and salt. This synthesis of a complex substance from simple ones is typical of the chemistry of the future. But to take full advantage of the possibilities that lie in this direction, we must learn how and why a catalyst works. For the benefit of those who complacently believe that chemistry has attained a high degree of perfection,

PROFESSOR ROGER ADAMS

OF THE UNIVERSITY OF ILLINOIS, PRESIDENT OF THE AMERICAN CHEMICAL SOCIETY.



JOHN WINTHROP, JR.

Dr. Nieuwland stated bluntly that we will never really understand catalysis until we know how to make a potato from carbon dioxide, water and ammonia.

Dr. Frank C. Whitmore of Pennsylvania State College called attention to the fact that if Dr. Nieuwland had had his hands multiplied by government subvention, his contribution to our scientific knowledge would have been incalculably greater. The first is that hundreds of young, well-trained chemists are working in many of our industrial laboratories under comparatively incompetent supervision; careful planning would have had these men working instead under the direction of scientists of the caliber of Dr. Nieuwland.

In these days of consumer-worship, the plea of Dr. A. C. Fieldner, of the U. S. Bureau of Mines, for conservation, seemed heretical. Fortunately our "visible" coal reserve, 3½ trillion tons, is so vast that its exhaustion lies in the distant future, but it is not so with oil. If the present rate of consumption is not increased, but is merely maintained, our reserve of 13 billion barrels will have been exhausted in 15 years. Dr. Fieldner suggested prolonging the life of petroleum by using coal for all ordinary heating and for stationary-power generation. Another obvious conservation measure would consist in stopping the conversion of petroleum into alcohol, even though for the time being this alcohol is cheaper than fermentation-alcohol.

PROFESSOR EDWARD BARTOW

OF THE STATE UNIVERSITY OF IOWA, PRESIDENT-ELECT OF THE AMERICAN CHEMICAL SOCIETY.

Careful planning would permit agriculture, not the petroleum industry, to be stimulated by our increasing alcohol requirements.

On its side, the petroleum industry has taken a notable forward step by building up complex hydrocarbons from simpler ones. Dr. Vladimir N. Ipatieff, of the Universal Oil Products Company, described the polymerization of gaseous hydrocarbons to liquids of higher molecular weight. An accidental, but highly significant feature of the gasoline so produced is its high octane number. It enables engines of higher compression to operate without knocking, which means increased efficiency, and possible airplane speeds of 500 miles per hour. Thomas Midgley, Jr., of the Ethyl Gasoline Corporation, hazarded the guess that the 1,000 mile-an-hour plane is just around the corner.

Chemists have begun a serious attack on the problems of the construction industry. The exact mechanism of the setting of cement is not yet known, but experiments toward the solution of this problem were described. Other advances in the field include the expanding use of aluminum, nickel and stainless steel in buildings, and a synthetic stone of low density to permit increased height without impairment of structural strength.

In medicinal chemistry, several advances have been made in the elucidation of the structures of therapeutically important substances. Especially notable is the work of Drs. Craig and Jacobs, of the Rockefeller Institute, demonstrating the indole nucleus in the alkaloids of ergot. This should make possible the synthesis of these alkaloids, an accomplishment greatly to be desired, owing to the present variable activity of different preparations of ergot.

Robert R. Williams, of the Bell Telephone Laboratories, who has for many years pursued the study of Vitamin B_1 as an avocation, reported the presence of the thiazole nucleus in this vitamin. This is of unusual interest because thiazole has never before been observed in a natural product. Dr. Willard M. Allen, who received the Eli Lilly Award in Biochemistry for his work on progestin, gave an account of the isolation and the proof of the structure of this hormone.

Dr. Paul L. Kirk, of California, described his extension of the micro-analytical technique to the determination of calcium, urea and other clinically significant constituents of the blood. Analyses may now be carried out with as little as 0.03 cc, as compared with the former minimum requirement of one hundred times this quantity.

A discovery which promises to revolutionize the planting and harvesting of a portion of the grain crop was reported by C. F. Schnabel, of Kansas City. Young shoots of oats, wheat, barley and rye have two to five times the vitamin and protein content of spinach, lettuce, carrots, etc. Two or more crops of these young grasses can be grown each season. The vitamins are preserved by dehydration, and the pulverized product is palatable when mixed with other foods.

What of the future? This was answered in a rather breath-taking manner by Thomas Midgley. In fact, if a scientist of lesser achievements had made the predictions, he might well have been open to the suspicion of having his tongue in his cheek. Among the less startling developments which he expects are control of the growth of live stock by synthetic hormones, the end of colds, tuberculosis, diabetes and septicemia, and indefinitely prolonged life (if desired). In referring to the advent of a two-hour working day, Mr. Midgley was obviously speaking for the executive, for the most agile chemist can scarcely hope, for example, to complete a fractional distillation in this interval. And no self-respecting chemist of the future, I take it, would consider a single distillation a day's work.

THOMAS B. GRAVE

THE SCIENTIFIC MONTHLY

AUGUST, 1935

THE CURRENT CHAOS IN PSYCHOLOGY:

AND THE WAY OUT VIA PSYCHE'S DESIGN FOR LIVING

By Dr. JOSEPH JASTROW

"First there was ooze; then there was mud; then there was building material; and then the world began." Such is Mr. Dooley's unofficial account of evolution. It may suggest a slight parallel in the course of psychology, leaving it open which of the prevalent solutions in our own days or among those of our forerunners are ooze, which mud and which building material. How cosmos came out of chaos is the *Ur*-myth of creation and knowledge. Why in psychology the chaotic condition continues, despite a rainbow promise of cosmic fulfilment, is the overture of my theme.

I

The chaos pervades every Rialto where psychologists congregate. When informed that Mr. Quidnunc is a psychologist, the layman remains in doubt as to what may be the tenor of his occupations and commitments. It is still a guess whether said Professor Q. makes motion pictures of the squirmings of unborn guinea-pigs or of the first gosling steps of regimented infants rampant and couchant; whether he interprets dreams and cures stammering or discovers and relieves frustrations; whether he deals in egos and ids or in configurations, in conditioned reflexes or unresolved complexes; or whether he measures the appeal of moronized advertising or demonstrates in wiggly graphs how to save motions in manufacturing merchandise that probably has no excuse for being. I make little complaint of his indiscriminate versatility, though it offers an opening for the underworld practitioners—the psychological racketeers who are very much in the ugly picture of the commercial exploitation of Psyche. The confusion of tongues goes deeper than a difference in dialect or a divergence of message; it is a jargon of concepts, a Babel of designs or the aimless futility of a lack of one. The chaos results from an infirmity of insight at the initial stages which precondition building-plans. The way out of chaos is through a quest for a golden but accessible fleece—Psyche's design for living. For this, first and last, is the whole of psychology. That is my major theme. Psychologists, whatever their special interests, are all professional students of the life of the mind; and they are nothing other, nothing more. Could we turn the clock back twoscore years and start anew with that insight, that agreement of purpose, the road to Cosmos would have been, would now be plainer and smoother. History can not be unscrambled; the might-have-been school of exposition is without honor and without joy; yet post-mortems, inevitably belated, are singularly convincing.

In that mood, I shall indulge in a moment of professional retrospect—which

same is a dignified pursuit, not to be confused with the reminiscent garrulity of unredeemed longevity. This flash-back will reveal how much has been done in draining the ooze, converting the mud and collecting the building material for the house of psychology; how much progress towards cosmos and emergence from chaos has actually occurred since our climactic century began.

Taking a daring and dismal dip into autobiography, I summoned the courage to read my own presidential address to the American Psychological Association in 1900. It was delivered at the precocious age of minus 3, according to the Pitkinian life-clock, accepted by the mature with alacrity, because it delays registration until 40. At this temporal distance the silences of that day sound louder and stranger than the mentions. The I.Q., like myself, was still to be born; Freud, though articulate, was known only, and that very slightly, to the very few of us in touch with Vienna. Behaviorism was in rompers. On that occasion I felt it incumbent to proclaim that a psychologist was not primarily a spook-hunter nor was his chief diet tales of psychic long-distance communication and trance revelations. In the public eye, psychical research distinctly overtopped psychology proper, which as an experimental pursuit was regarded as irrelevant prying, if not improper. James's not inept remark was going the rounds that the "prism, pendulum and chronograph philosophers" could only have "arisen in a country whose natives could not be bored."

I defended and selected as of greatest significance and promise the two movements then struggling for recognition: the precise study of animal behavior as the primer of human behavior, and applied psychology in its salient ramifications; I emphasized that the techniques of measurement, which would certainly come to be greatly extended, were to be developed not for analysis alone but for practical yardstick purpose. I was never concerned with maintaining the "purity" of psychology. In that day, this measurement of capacity was referred to with disdain as "mental anthropometry." I replied that, call it what you will, I was for it; and out of it grew intelligence tests, not always very intelligently tested. Another of my emphases was upon the significance of abnormal psychology, alike for its own sake and for its bearing throughout on normal phenomena. And my concluding claim was for the admission on terms of equality of psychology into the fraternity of the sciences. So much of anticipation has been fulfilled.

I likewise sketched the outlines of a position to which in recent years I have returned with, I hope, more competent understanding. At that time Stanley Hall was expressing his regret that psychology had followed the method and temper of physics—he had the maestro Helmholz in mind—rather than that of biology. It was "physiological psychology" in name only, and remained so in half-hearted and eclectic fashion. Up to our own day, texts in psychology introduce a chapter on the nervous system at the beginning or in the end or in between, with no very close evidence of its bearing on the other chapters; neurons were just handy things to know about. That defect has in part been remedied, but far from completely so. Much of the credit of the advance belongs to the principles behind what we must perforce call Behaviorism, though I object to the 'ism and don't like its behavior. We were all so plainly behaviorists *de facto* that we saw no reason for the ceremony either of baptism or of total renunciation of our goods and chattels. Yet none of us, I admit, heeded the theme sufficiently. The lusty if somewhat croupy cries of Behaviorism grew to a belligerent challenge. That it made a noise like science

we must concede, and also that it clarified the atmosphere and in some measure directed the line of march.

In my case it made explicit—yet with low illumination—the approach which I formulated as naturalistic, but did not promulgate as such until many years later, when it became evident that the terms "functional" and "dynamic"—which were more freely used—had no teeth, hardly even gums. These terms indicated the obvious desiderata, yet supplied neither principles nor programs. Under that provocation, I unfurled my banner; though banners and processions, and camps and campaigns, and above all controversies are not at all to my taste.

Maturation is a process not confined to infancy; it is even more essential to the professorial status. All this is relevant only as a confession of how one man's psychological neurons acquired their medullary sheaths. The most democratically distributed of mental qualities—except stupidity—does not appear as a chapter-heading in the psychological texts; it is called hindsight. Even Pitkin's monumental tome on stupidity—the mere handling of which is a muscle-building exercise—has a scant reference to it. It is part of the compensation of retirement to find one's bump of hindsight visibly and tangibly enlarged.

By these stages I came to be a naturalistic psychologist, and declare with a small probable error that most of the guild, who carry no banners, belong to the same camp. In my own lifetime, psychology has become an established naturalistic science. There is a large settlement in cosmos despite the persistence of chaos.

II

Such are my credentials for speaking out in meeting. I proceed to deal with the contributors to chaos. Exhibit A is the much and unavoidably discussed "Behaviorism," which in my manuscript I place in the straight-jacket of quotation marks. You have heard of the mathematical theologue who calculated that the world was created in the year 4004 B. C. on October 10, at 9 o'clock in the morning, Eden standard time. Content with a less precise birth-date, Watson placed his creation in the year 1912; then psychology had its genesis, by an expulsion from the miasmic garden of introspection—a fiat exodus, by sweeping away mind and consciousness and all their baggage as "carryovers [the historical minded will squirm] from the dogma of the Middle Ages." To the accumulated doctrines that bore the name of psychology, Watson said "Scram!"; and we are assured that they scrammed. To informed sophisticates it is needless to consider the series of statements, sponsored by popular magazines, which Watson set forth as the issues and rewards of a behaviorized generation, as he visioned it in blurb-like commendation. This phase of what has been called Watsonianity represents the less responsible expression of a position which in its sober pursuit has a message of consequence.

However, I can not ignore the ignoring; for that is article number I in the creed. I cite Holt, who, like myself long ago, acknowledged the clarifying effect of "Behaviorism," which was bought "at a singularly high price." "So far as I understand Behaviorism, it flatly denies the existence of any psychological problems." He adds: "Now exorcism by verbal denial is a form of word magic that seems to me more primitive and rather cruder than the other."

Yet this technique of ignoring—even more effective than ignorance—is not original with Watson. An earlier adept in a different field was the inspired author of "Science and Health," a title chosen because the volume vigorously and volubly ignored both. The most

wide-spread doctrine of "Behaviorism" is that what we become is the issue of conditioning; chromosomes are so much alike that, like the flowers that bloom in the spring, they have nothing to do with the case. And yet I find it difficult to imagine that by the most radical differences in their early training, there could have been developed a Mary Baker Watson and a John Broadus Eddy. Germs and germ-plasms are but two of the thousand inconveniences of facts.

Article II in the 'ism of behavior is the complete adequacy of the stimulus-response, the S-R formula. The acceptance of the mighty S-R as a solution is one of those sporadic, almost inexplicable lapses from logic to which the scientific mind is subject. It is not the only instance in which the entire play has been written without the character of Hamlet. The vital clue to the authentic fragment of design for living contained in the reflex or related scheme lies in the essential but here omitted O—organism. That the formula obviously reads S-[O]-R, the S and R owing their being solely to the O—is a conclusion well within the comprehension of high-school graduates. Without the O, the S and the R are as fanciful abstractions as the grin of the Cheshire cat.

The "behaviorist's" S-R formula[1] is so tangential that it serves more readily as the fabric of a joke than of a serious proposition. It was so used, when it was said of an habitual after-dinner speaker that all you had to do was to put a dinner in his mouth, and a speech came out! A perfect example of stimulus and response, and the neglect of all the relations that connect them—which is their psychology.

Only slightly less obvious is a still more fundamental fallacy, confusion or ignoring in this S-R, push-button, slot-machine psychology. It ignores not only the internal contrivances which humans share with slot-machines, but the vital consideration that what converts any of the potential events in a crowded multifarious environment—an A or a B or a C down to a Z—into an S, an effective stimulation, is an essential part of the problem and the nub of it. When and how does a potential S become an actual S?—that is the whole question. If all the exhibitions of cosmic, physical, chemical energy by which we are surrounded were active stimuli, we should be living in a 20-ring circus from dawn to dusk, and not relieved then; for I'll take my illustration from night-life: Cattle exhibit an imperturbable and, if you think so, enviable placidity in the moonlight; their retinas, like ours, see it and see by it. For reasons satisfactory to bovine nature, the moon just isn't a stimulus any more than a transit of Venus. What the moon will do to romantic human couples, including making a transit of Venus of it, is beyond prediction of even the "Behaviorist," who stakes his all on the predictability of conduct.

Article III, the conditioned response, is the Atlas on whose shoulders rests the "Behaviorist" world. The conditioned response is a fact, the technique a significant discovery. Its place in the design for living is uncertain. I am concerned with its unwarranted extension and application. Here the ignoring is of the relations, the evolutionary levels, which, we all agree, set the problem of correlating types of behavior with the neural

1 For the legitimate use of the S-R formula, I refer to the lucid and critical work of Thorndike. "The inappropriate word *conditioning* has come into use as a name for two very different, but often confused ways of modifying behavior." Making clear that the "techniques" involved in the reflex, "saliva" type of conditioning can not be extended to ordinary forms of education, he proposes "*associative shifting*" for the second use of the term *conditioning*. This is applicable, is indeed, of predominant value in the educative process. Out of this acorn of confusion has grown a forest of oaks of misleading psychology and pedagogy.

constitution. The behaviorist passes from a salivating dog to a cerebrating man with no sense of crossing a series of frontiers in a vast continent. Selecting a high-level bit of behavior, I make myself the goat of an illustration. If I addressed gatherings of psychologists early and often, and if they were prone to conditioning, they could never see me again or ever hear my voice over the radio, without feeling an inconvenient urge to assemble a psychological meeting; or they could never again attend any such meeting in comfort, because they would be haunted by the reverberations of my operations on their auditory neurons. My colleagues will readily agree that under such conditions, the value of continued existence becomes problematic.

Or, speaking more plausibly to one and all: If you had music with your meals, you might either come to accept the music and dispense with the meals; or you would get hungry when you heard music; or you could not eat until the band started to play. Even the course of conditioning, once it leaves the primal neural level, is indefinite. Music does not get conditioned to eating nor eating to music, however much dogs may be taught to salivate and boarding-house inmates to form a flying wedge when a gong sounds. And consider loftier things: if whenever you heard the wedding march, you had an urge to corral a bride—whether or not you had a wife at home—the conjugal life would be even more complicated than it already is. And it is not when I hear the funeral dirge, but when I am forced to listen to crooners, that I feel the strong urge to provide the corpse. The moral is a big one: you can't solve a problem by running away from it, nor can you propose that the solution of a chess-problem is to substitute tick-tack-toe.

The loud-speaker truth is that the development trend of the nervous system is toward freeing the organism, and human behavior maximally from conditioning; we owe that boon to its complicated integration. The higher the organism, the higher the function within it, the less is it subject to conditioning of that salivary order, at that lower level of integration. There is in the doctrine of conditioning a legitimate but limited truth; yet I accept the full consequence of the deduction that the elaborate and ingenious investigations conducted in modernistic, streamlined psychological laboratories on that premise—and gloried in as immaculately conceived, without subjective sin—are barren, technically sophisticated and logically naive. Furthermore, the attempt to construct an entire psychology from a piecemeal fragment is equally futile. It is true that the paleontologist is fairly successful in such restoration from a tooth alone, because he regards the total organism of which the tooth is a fragment; had he proceeded by the logic of "Behaviorism," he would have made the antediluvian monster all teeth. The partition line between the sublime and the ridiculous is slight; for the same reason an analogy shades into a joke, which, when it is mistaken for science, is no laughing matter. And that sententious lesson forms an easy transition to the next contributor to chaos—the 'ism of Freud.

III

Equally challenging is psychoanalysis; but its temper and *metier* are of an entirely different origin and order. Assuming a familiarity with its tenets, I shall focus upon its central logical and psychological disregards—sins of omission and commission; by these the domain of chaos was thrown wide open. Freud did not set out to be a psychologist; in some of his more confessional statements there is a tone of regret that he had to

become one. His career began in a youthful visit to the Paris of Charcot and later. A problem which Janet envisaged but did not develop became a foundation-stone of his edifice. Freud refused to accept the hysterical phenomena at their face value. He sought their determination, recognized in their detailed picture a fragment of a design for living, and a strange one. It was living by escape, by an unrecognized order of conversion. There was much talk then and long before of the influence of the mind on the body; there was no real penetration into the mechanism involved. The topic was instantly enriched by Freud's principle of motivation; furthermore, the primacy of the emotional factor in response received a novel and far-flung emphasis. By the same insight, the realm of Psyche—which had been far too exclusively intellectualized—was notably enlarged by the inclusion of what came to be formulated as "the subconscious," crystallized too limitedly in Freud's Unconscious. By these and related *auseinander-setzungen,* Freud became a pioneer in the overlapping territory of psychology and psychopathology. He may be said to have added a new dimension to the contours of Psyche. His place is assured; we shall never return to a pre-Freudian era. So much of tribute is as gratefully rendered as it is deserved.

Yet it is my seemingly invidious task to consider Freud and his following, for which he can not disclaim responsibility, as potent contributors to chaos. The justification of my position became a book-length critique.[2] I ascribed the great misleads of psychoanalysis to its extravagant and illogical applications. It is a matter of momentous regret that so independent and creative a mind as Freud's should have so weak a sense for the logic of facts and relations. All scientists above the rank and file must be competent in the craft of the logician; they must be logic masters no less than knowledge masters. In no *Fach* is that rigorous discipline so indispensable as in psychology's treacherous realm; there the adventurer must be stably footed and well shod. Unfortunately Freud was neither; his psychological flair is exceptional; his logical ineptitude equally so. It is presumably a vain regret to bemoan the rarity of the conjunction of creative vitality and logicality; that dispensation is in the lap of the gods, or, if one prefer, of the chromosomes.

On more than one occasion, when citing a Freudian instance or argument, I was suspected of inventing it or of purloining it from a questionable type of joke-book. The following nugget is seriously offered by Stekel. He concludes that chronic late-comers are apt to be the youngest members of the family. And this is why: Having missed so much by their late arrival on the earthly scene, which their older siblings were privileged to enjoy, they, by their tardiness, are taking a subconscious revenge upon them and the world at large. To unscramble the logic by which, in such conjunctions, cause and effect, stimulus and response, are brought into the consequential relation is hardly worth the contortional pangs it would involve. For those whom they would destroy, the gods have now available a new technique for their undoing: they need only make them orthodoxly Freudian.

Whether one samples the Freudian characterology—or the lapsology—the forgettings, accidental breakages, slips of hand or tongue—or the dreamology or the complexology, there is the same distorted and contorted reasoning—a preordained Q.E.D. Says our great master-logician, Charles S. Peirce, "If the conclusion determines what the reasoning shall be, the reasoning is sham."

That the doctrine implies certain assumptions—not without a factual basis

2 "The House that Freud Built," 1933.

—is equally evident—among them that of the dominance and penetration of sex throughout Psyche's design for living. There results the picture of *Homo Freudiens,* a caricature, despite recognizable features. As weird a wisdom as any is the derivation of such complex traits as conservatism, reticence and parsimony, from infantile over-attention to eliminative processes. By the same logic the proverbial hyper-thrift of the Scotch becomes a racial resultant of chronic constipation. Since withholding is withholding, purse-strings and sphincters are apparently of a nature all compact. Competing with a glandular psychology is this bizarre orifice psychology. Had the human body more orifices, we should be still more fearfully and wonderfully made.

I can say no more nor even touch upon the practice of psychoanalysis which proceeds upon the same bizarre and bewitched logic and has the courage (or should I say the bravado of its convictions?) even to developing the doctrine of transfer by which patient and analyst must enter into a companionate, erotic relation in a Freudo-Pickwickian sense, first forging and then dissolving the bond —a Gretna Green and Reno in one office. What else than a total wreckage can result from such piloting of the craft? No wonder that our scientific confrères turn up their noses at the entire malodorous product or see little to distinguish between Freud's professional treatise on dreams and the proletariat handbooks merchandised by the Maison Woolworth. And yet they are not sisters under the scalp; for there is a scientific intention in the Freudian scheme; or it would not be worth consideration. The movement must be reckoned with as a clue to psychic life and in the design for living, if peace is to come on Psyche's earth and good will to psychologists. We must retain our sense of logical justice and distinguish between the validity of the network of concepts and the in-valid structure built upon them.

Consider the subconscious, Freud's Unc, which is an authentic factor in Psyche's design. Can it be naturalized? Where can it be placed in the scheme of nature? Freud does not even raise the question. He accepts the proof of its being as supplied by case-histories as they emerge from the analytical confessional. But Rivers, with a keener biological sense, attempts to place it. On strictly neurological data, Head and he formulated the concepts of protopathic and epicritic, which belong to Paleozoic psychology; and Paleozoic psychology, I contend, is one of the foundation-stones of a naturalistic scheme. There are lesson-bearing vestiges and rudimentary reactions in the fossil-bearing strata of human psychology. There if anywhere, functioning at the primary level, the subconscious should find its roots.

But Freud's subconscious is posited for an order of Psyche's realm evolutionarily as remote as possible from that. It operates in scruples, repressed desires, aversions and compulsions and entangled plots—elaborate cerebrations all. I can see no possibility of its naturalization until the concept is entirely remodelled, with the ego and id and super ego transformed out of all Freudian recognition. The same critique applies even more drastically to Jung's racial subconscious. Complicated patterns of response, with all their baggage of acquired characteristics, have no place in the evolutionary heritage.

IV

A science that can survive two such invasions must have a lusty constitution. I have proclaimed my faith in salvation, if with singleness of purpose we seek Psyche's design for living. If we prefer —as does Dunlap from one approach and

Adolf Meyer from another—to call ourselves *psychobiologists,* the enlistment is the same. In either event it follows that the first stake must be driven in the territory of neurology.

That turn of the road may be dated from Sherrington's masterly contribution on the integration of the nervous system. Integration is the indispensable clue to the life of the mind as rooted in the neural structure and function. Marston's proposal of integrative psychology is completely valid; but he carries out his original and important scheme in a selected domain. His orientation is correct and his conclusions significant. Again, I must skip where I would linger. I should like to present the "reflex" chapter in psychology as it appears in a naturalistic setting. Far from minimizing its value, its representativeness is enhanced; it proposes problems which even Fearing's comprehensive study failed to bring into the picture, particularly the several orders of reflexes and their genesis and career. But it gives no sanction to the apotheosis of the reflex, which in Herrick's words is "an attempt to construct a working model of the nervous system and all that it does in terms of hierarchies of reflex-arcs conceived as rigidly insulated systems of conduction built after specifications resembling those of an automatic telephone exchange. . . . The twentieth century has seen the collapse of this imposing structure. The actual conduct of animal and human bodies is not fabricated by monumentally piling up simple reflexes. Such a structure is not stable and would fall apart."

Before proceeding, I must mention another signal landmark of Psyche's design for living, a station on the road to our present enlightenment.

We must remember that this nervous system of ours has been very, very long in the making, and mind in the making has the same extensive course. Evolution is a master key for naturalistic psychology. The script of the brain can not be read by anatomy alone; its clue is in its genesis and genetic stages. There results an illuminating distinction between the older and the newer brain. That guiding light is priceless; without it we should be in the dark, and the brain a hieroglyphic maze. As a single instance consider the cerebellum. No mere dissectional study would recognize that this organ belongs to two different epochs, the central lobe (vermis) to the old brain, the lateral lobes with their great cables of strands connecting with the cerebral lobes, to the new brain. And in this fact lies an epitome of meaning.

I pass on to a new vista—so recent that to many it may be wholly unfamiliar, which I regard as equally reconstructive with the great stations of enlightenment I have singled out for mention. I return to my own experience. Despite the composite illumination of the life of the mind by the neuronic cosmos—and what a contrast between now and the days when I was first introduced to the intricacies of the nervous system!—I had long felt that there was something missing or something wrong, that despite all the decipherment, we did not have the story rightly. It was a good fit of a psychological suit of clothes to a neurological body of facts, but far from a perfect fit; one suspected wrong cuts here and there and many where.

About a year ago, after several vain attempts at the puzzle, a radical idea loomed on my horizon. It questioned the usual but inevitable horizontality of the neural blue-prints. Here was the spinal level of performance, and there the medullary, and then the mid-brain, and then the cerebral level. But was all this not an artifact of our methods of study? Nature never made any cross-sections. Nature's scheme is an ascending evolutionary one of increasing and differen-

tiated function. Following that clue, there results a vertical picture. It is arrived at by a refocusing of the neural design. It asks this question—What are the first and indispensable neural instruments of life which attain a psychological status? What is the archigenesis of it all? I sighted a glimpse of the promised land.

I was soon to find that my little Columbian egg was not wholly my own. Obviously so far-reaching a conclusion must have neurological authority. The psychologist may propose; the neurologist alone can dispose. Accordingly, I ransacked the appropriate sections in the recent literature in the Library of the N. Y. Academy of Medicine. It was almost the last item in my list that gave me the momentary shock of finding my scheme anticipated, and the lasting pleasure of support from high authority. The scheme is that of Professor L. R. Müller of Erlangen. I express my confidence that the Müller contributions will be recognized as equal in significance with the stages of insight which I have singled out for mention. The remarkable coincidence is that we should both have been led to ask the same question. The close parallelism of our answers is almost inevitable. Professor Müller made clear to me a distinction over which I had fumbled. I recognized that we were using "function" in two senses: the function of the retina was to receive the light rays, of the crystalline lens to focus them, of the iris to regulate the amount of light, of the muscles to explore the field of vision and of inner and outer muscles in addition to accomplish binocular foveal vision; or *in toto* and in the vernacular, we have eyes to see and ears to hear. These are all specialized functions; but what does vision mean in the design for living? That is its service in the total life equipment; and service is the comprehensive, illuminating, integrating conception. The German has two words, having adopted *Function* and having its own word *Leistung,* for which "service" is our best rendering. Hence the title of Dr. Müller's[3] pamphlet reads *Die Einteilung des Nervensystems nach seiner Leistungen* (1933), indeed "*nach seinen seelischen Leistungen*"—psychic service. *Psyche's design for living is a compendium and an issue of the psychic services of our neural structures; it stems there. By following that clue, psychology remains loyally naturalistic.*

V

The Müller *Leistung* scheme reads thus: The primary neural service is of the *vital* or life functions. For this we both used the same term; we could hardly do otherwise. Life before mind, business before pleasure, the lower before the higher. For this insight, the amazingly rapid accumulation of the knowledge of the autonomic nervous system had prepared the way. To list a few of the life-functions which attain—and here I am following my own exposition—psychic *representation* and in variable measure *control;* there are the neural mechanisms of bodily warmth through circulation, eventually the rich circulatory—flushing, blushing, blanching, pulse acceleration and retardation; there is the respiratory—breath-holding and panting psychology; there are the metabolic processes and specifically the nausea complex; the sleep mechanism; the perspiration syndrome; the pupillar reflex; certain dermal (protopathic) and tendinal reactions; the sex tensions and the subtle and varied endocrinal influences. And there, and not in ooze or mud, is where Psyche's world began.

[3] I wrote enthusiastically to Dr. Müller and suggested the importance of making his views accessible to English readers. Again a coincidence! Dr. J. Salisbury Craig, of Glasgow, similarly impressed, had already translated the essay and was looking for a publisher.

The second question reads: What is the next order of service in the ascending level? What more must the body—the body-mind or the mind-body—do to maintain itself, and ever on the road to psychic control? The answer, somewhat less obvious, became apparent when one thought—and that was my train of inquiry—of the maturing functions in the infant. The second great order of service was the maintenance of *posture* and under increasing variable conditions—eventually sitting, standing, walking, running, jumping, dancing, by which time the higher directorate was partly and then fully in command. I called it the *stato-motor* service, Müller the *myostatic* system, which is also the *myotonic* system, for tone is essential to right control.

In the vertical, which is likewise the integrated, scheme thus plotted, the cerebellum has a commanding place in the second division. It is the stato-motor, central organ *par excellence.* Its relative independence in lowly organized creatures, its congenital functioning or early maturing—from chick to foal—all fall in line in the picture. The organ of equilibrium—the semicircular canals—as the sensory provisions, the kinesthetic complex on the motor side, constitute the main apparatus of the stance and posture (*Stellung* and *Haltung*), the basic motor expressions in their life-service. Within this group must be placed the behavior of the facial musculature, the innervation of the mouth center—fairly reflex in sucking, yet with crying just as innate—and expanding into smiling, weeping and the facial expressional repertory. The primacy of the effective life appears equally in its share at the autonomic (vital) level and in the facial mimicry at the second order; and later, the taking over, as is true of much of the entire stato-motor and allied realm, by the central control, when the infantile smile becomes the socialite's greeting, and the face, like language, is divided in service between revealing and concealing thought. The initial taking over of this service by voluntary direction is precisely paralleled by the successive appearance of the medullary sheaths.

The third completing system is familiarly the cerebral, in its highest levels the cortical empire of reception, interpretation and control. The suitable name for the culminating service, which is Psyche established, is the adjustment-of-organism-to-environment service. In Müller's terminology, it is the *systema nervorum pro mundo,* or the *Umwelt Nerven System.* I arrived at my own formulation by following the accepted division of the sensory orders: the *enteroceptors* of the vital system, the *proprio-ceptors* of the stato-motor system and the *exteroceptors* of the (adjustment to) environmental system.

I called it the externalizing service with its major headquarters in the fore brain, yet with many an affiliated nucleus scattered through midbrain and hindbrain, according to the sensori-motor mechanism involved. It is again a vertical picture, but with the head—the first in contact with the *Umwelt*—as the concentrated massing of the receptive forces. Hearing, seeing, touching form the great recognitional triumvirate, the alert greeting-committee in *Erkenning der Umwelt,* the Greek *gnosis;* corporal management, manipulation and speech form the great motor effectors, the extensive *Wirkung auf die Umwelt,* the Greek *praxis.* Thus cortically taking and giving, we spent our days. We have reached Psyche's complete design for living.

Draped on this framework the entire construction falls into neater order. We have a map with a code to its meaning, instead of a topographical survey alone. The service view of the nervous system and behavior retains the values of the

functional and dynamic and extends their scope. It might well be called "service psychology"; but it is all so inherently naturalistic, interpreting the nature-made devices and their further careers, that the scheme becomes the preferred representative vehicle of naturalistic psychology concerned with original fitness and survival values.

Beautiful in its orderliness, simple in its natural logic, convincing in its harmonious composition, the further value of the service view—which is still just a scheme—lies in the multitude of special problems—the familiar content of the psychology, which it illuminates. It was to me a source of keen satisfaction, akin to that of the archeologist or the fossil restorer, to see how the entire repertory of functions fell into line under the Müller reorganization—a veritable NRA for psychology.

VI

I select one example out of a score—that of the vexed problem of instinct. Once more I found my own presentations anticipated and improved upon. The Müller theory of instinct is remarkably simplifying. It reads, in my own formulation, that the nub of an instinct is the urge to use an organ. That is its prototype. The principle develops and spreads into many corollaries. This clue to instinct had been now and then recognized, as by Thorndike in naming the instinct of manipulation, yet it was all casual, for he recognized half a dozen other types of instinct as well. Having that organ—the hand—we have the urge to use it. It is the hand-using instinct. We happen not to speak of the footing instinct, but such it is, with its tendency to stand, walk, kick and, in other creatures, to dig or strike. There is also the mouthing instinct, with its repertory. It is obvious that nature does not create an organ without implanting in the organism the urge to its use, together with a bit of a recipe how to use it. The sex instinct is as clearly focused on the use of an organ, with a powerful urge behind it. If we had horns, we should have a butting instinct; kids display the urge even before the horns sprout. The marvel is in the organ; the recipe—the set of instructions in organic terms—goes with it. Such is the core of instinct; its radiations are endless.

Snakes, having fangs and poison-sacs, have the complicated urge to use them, and no less the spider to trap the fly. The spinaret and the web-spinning instinct came into existence together; they are one. But once spun, the lying-in-wait at a strategic point, the sensitiveness to the vibrations, the pouncing upon and further enmeshing of the prey follow. Thus do instincts form an interlocking directorate, as indeed they must, to be effective in life service. Organs and their service set the course of instincts.

The further problems of instinct center about their patterning and their versatility, how they become less rigid and more plastic and thereby expand their circuit of influence. Teeth can only bite; paws and claws are more versatile, hands most so. The versatility of the entire body is reflected in the patterning of instinctive responses. There is the theme of the chapter in naturalistic psychology, which would reorganize the endless and aimless, confusing and superfluous discussions concerning instinct which fill so many chapters and volumes tediously and misleadingly.

As they appear to me, the three mystic or mysterious members of Psyche's crew are instinct, emotion and consciousness—always veiled and shrouded, even as they show their features. Yet, within the naturalistic limitations, they can be brought into line. Once more the chaotic confusion is resolvable into a cosmic scheme. Emotion starts too high up; as

we use the word, it has clinging to it a cluster of implications. We must have a broader and a simpler, a more naturalistic word, and have it in the term "affect" already naturalized. In my scheme, the affect and the reflect start and proceed together. They are aria and accompaniment, now the strategy dominant, and again the feeling tone in the ascendant, the obligato fusing with the theme.

In the lower strata, affective psychology takes the lead; in the higher reaches reflective psychology is at the helm, though ever with a dual control. Of this I am confident: that the floundering analyses of the emotional life result from false emphases and partial perspectives and pursuits of wrong trails, that their correction and completion lies in the same province and method that I have indicated. The evidence is many-sided, and forms another chapter in the naturalistic version.

Once more the instinct problem in its affective aspect becomes a salient illustration. There was a bit of a splurge a quarter century ago, when following a hint from James, Shand announced the engagement of instinct and emotion, and McDougall proclaimed the bans and sent out wedding cards. I received one myself and accepted, which now I regret. It seemed at first blush an illumination that fear was the flight instinct and anger the fight instinct. McDougall recorded the primary instincts in "We Are Seven!" terms, coupling the parental instinct with the tender emotion and creating for self-abasement as an instinct negative self-feeling as an emotion. It was all so much more verbal than real, and nature was fairly out of the picture.

Hence another brand of chaos, another psychological game, which unfortunately, as the French say, was taken *au serieux*. So the couples march in two by two respectably into the psychological ark. They are paired without prejudice, sometimes Mr. Instinct with Mrs. Emotion, and sometimes Mr. Emotion with Mrs. Instinct, but all amicably and without scandal. The assignment becomes more discretionary after the major couples have been assembled, and there seems to be some danger of unmated instincts or unwed blessedness or bereavement. The pairing makes strong drafts on hypothetical circumstances. In a flippant mood it reminds one of the two companions delayed on an expedition into the woods far beyond the lunch hour and regretting that they had brought no provisions. The more academically minded of the two speculated: "If we had some ham, we could prepare ham and eggs, if we had the eggs." I mean no discourtesy in referring to what Dr. McCurdy calls this "comfortable list of instincts" as the ham-and-egg theory of instincts and emotions. They are naturally and not merely conventionally served together; but the combination sheds little light on the natural history of either member of the conjunction. Through psychological sponsorship, this has become the favorite diet of the sociologists, to further confounding.

Under any closely naturalistic study, this neat and comfortable consignment, and indeed the entire problem, becomes a chapter in the "affect-reflect" evolution. Scan the long list of instinct classifiers, Thorndike, Hocking, Watson, Warren, Woodworth, Calvin and Bagley, Kirkpatrick *et al.*—able minds, contradictory and confusing, because engaged upon a futile quest. Much of the problem disappears and the rest of it reappears in consistent orientation, once the naturalistic clue is completely accepted. In its absence and in the absence of the analytic guide, there arose the vogue of collecting, which the book of Bernard collects in a veritable Who's Who in the Instincts, demonstrating not the embarrassment so

much as the absurdity of riches in fiat money. It has come about that a psychologist who has not clothed his system with an outfit of instincts seems in fear of being mistaken for a nudist. For myself, though I have succumbed mildly to collecting old pewter and Persian pottery, I have never collected instincts, and now rejoice in my freedom to see the problem unencumbered. Instinct finds its place quite naturally in the urge-outfit of the organism. Instinct is urge and instinct is strategy; they proceed together by decree of nature in wholesome naturalistic function.

Possibly an even more baffling bone of contention—if bones can be said to baffle—is consciousness, at the very mention of which robust "behaviorists" pull up the sheets over their emancipated heads. Consciousness—but no less so the neural counterpart of whatever it may be for which we require a name to conduct our psychological life—remains a mystery, but not a myth nor yet a bogey. The Prince of Denmark may be melancholy by lack of guts and excess of frontal lobe; but the pale cast of thought that sicklies o'er the native hue of resolution represents the urge to the life abundant—a yearning for bigger and better consciousness. That is the very keynote of the striving upward and forward to as rich a consciousness as the neuronic traffic will bear. Civilization[4] can not be otherwise interpreted.

I have moved along, following the major trends of my argument, without finding any peculiarly cogent point for recognizing a vigorous contribution that goes by the imported name of *Gestalt* psychology. I do not place it among the contributors to chaos, though it adds to the contenders for a throne the sovereignty of which belongs elsewhere. In one mood, it seems to me a short story enlarged without notable benefit into a novel of "Anthony Adverse" proportions; in another, it impresses me as a "third party" insisting upon making a major issue of a group of contentions to which the other "political" parties would be willing to subscribe if they were not made the entire platform. With the central proposal of *Gestalt* I am wholly in accord, without any deep sympathy with the minuteness of its methods and applications. In saying that its cardinal sin is the remoteness which it assumes—a sort of logical distance—from the scheme of nature in which the phenomena upon which they concentrate have their being. Carried far enough—and that the leaders have done—it posits a synthetic, denatured product for the realities; it introduces a new order of metaphysics into psychology. Naturalistic in the approach by which it finds its problems, once found, it insists that we must learn a new language to gauge their deeper value, which language is an Esperanto rather than the issue of the current experiences of men.

On the biological side, which means the neural function of the organism, the essential nugget of the principle is contained in the concept of integration. As by nature we work with integrated nervous systems, we move inevitably and throughout our being toward the total, patterned, meaningful interpretation of and equally the reaction to the world so full of a number of things that unless Gestalt-minded toward them they would remain in their virginal, buzzing confusion. The minutiae of Gestaltizing seem to me at times a moderately fruitful and often a decidedly fruitless occupation. *Gestalt* has done its work long ago; it introduced a correction and an elaboration—of the problem of perception mainly—which can readily be incorporated into the standard formulae. Its ambition and claim to be a psychology in

[4] Denison's "Emotion as the Basis of Civilization" has blazed the trail—the aggrandizement of consciousness is treated in his "Enlargement of Personality."

the wider sense, and to establish that claim by resort to methods which we are glad to have outgrown in favor of more pragmatic disciplines, condemns it far more than either the validity of its main thesis or the fine academic standing of its proponents recommend it.

VII

It is my contention that the naturalistic approach and scheme of psychology which I have outlined and for which the "service" view of the neural apparatus supplies a fitting foundation, brings into line a varied group of problems, clarifies many of them, restates some and dismisses still others. It is, as I see it, a potent transformer of chaos into cosmos, and not least so by the simple expedient of not getting lost in the woods of our own creation. But I have no intention of claiming any indiscriminately panaceal virtues for the scheme. Quite the contrary, it brings out distinctions indicating its boundaries. The dissolution of chaos requires no other magic than is contained in the wand of science, fashioned of the tried and true fiber of logic. Psychologists are naturalists—students of the life of the mind, seeking to decipher and interpret nature's design for psychic living.

Adopting Shakespearian titles for the versions of psychology which have articulately and vociferously been claimants to empire, "Behaviorism" becomes "A Comedy of Errors," Freudianism a "Midsummer Night's Dream," and Gestaltism" "Much Ado about Nothing"—or very little. In all of them there is much "Love's Labor Lost," and an intrusion of the wish-thinking which produces psychology "As You Like It" or "What You Will"; while, naturally, I should entitle my preferred way out: "All's Well that Ends Well."

THE THEORETICAL STRENGTH OF MATERIALS AND THEIR PRACTICAL WEAKNESS[1]

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If I am to fulfil the promise implied in my choice of a title for this discourse I must in the first place describe the grounds on which, it is claimed, a calculation of the strength of materials can be based: and then proceed to show that practice falls disappointingly short of theory, with reasons, so far as they can be given, for the deficiency.

It is only lately that calculations of strength have been possible. It has, of course, been known for a long time that the forces which make the solid body hold together must be due to the conjoint action of the forces exerted on one another by atoms and molecules of which a body is composed. But so long as there were no means of examining fine details of the composition of a solid and there was consequently no exact knowledge of its structure, nothing could be done. It would be impossible to explain the working of a machine without information as to the sizes, positions, orientations and mutual relations of its parts, wheels, axes, levers, pipes, containers, and so on.

In the case of a gas there is much less difficulty in explaining its behavior as a consequence of its simple structure. The atoms or molecules are flying to and fro, possessed of the kinetic energy which we measure as heat, and the properties of the gas are readily explained as a consequence of that motion. It is true that, when two molecules approach each other in the course of their movements, there is a comparatively short interval during which they are so close that they influence one another in ways which are characteristic of their nature and form. But in general the period is relatively very short and the effects of the influences are negligible.

When the temperature falls and the molecules move more sluggishly, the encounters become more important, and finally the energy of the movement is insufficient to hinder the tendency to association. The encounters become, so to speak, continuous, and the assemblage of molecules takes the form of a liquid. Even now the mobility of the molecules, which can slide past each other and change positions easily, renders their laws of movement comparatively easy to examine and the great subject of hydrodynamics is the result.

But when, the temperature falling still further, the molecules again lose energy and become locked together into a stiff structure, resisting deformation of all kinds, the properties of the solid body, so formed, depend upon the mutual actions of the molecules at very close quarters. These are certainly of great strength, and they vary from atom to atom, from molecule to molecule, even from one part of a molecule to another and sometimes from one part of an atom to another: they are sensitive to very slight changes in the distances of the centers of force from one another, and they are more active in some directions than in others.

[1] A lecture presented before the Royal Institution of Great Britain.

Clearly there is little that can be done to solve the problems of cohesion until the details of all these actions are known; and it is because the knowledge has not been available that the laws of the solid have not been discovered or even open to investigation, as have, to some extent at least, those of the gas and liquid.

In the last twenty years the situation has been entirely transformed. To begin with, the x-rays have provided us with a means of distinguishing the atoms and molecules of the solid, not individually, indeed, but when they are arranged in the regular array of the crystal, as is so often the case. We can now discover the structure of a crystal and the arrangement of the atoms in the unit of pattern, by the regular repetition of which the crystal is built up. And since all solid bodies are crystalline in whole or in part, or at least tend to be crystalline, our new powers extend over the whole of the solid range. The x-ray measurements, if they are carried out in full, give the average electron density at each point in the unit of the crystalline pattern. Up to the present it has not been the practice to carry them quite so far as that, and indeed the labor would be very great. It is sufficient to find the projection of the electron densities upon one or two of the important planes of the crystal. We obtain a picture which resembles what we should see if we looked through a vessel of the size and form of the unit cell; the vessel containing a transparent liquid in which various clouds were suspended. Each cloud would represent an atom; its density would be greatest at the center and would diminish towards the edges, fading away into the transparency of the

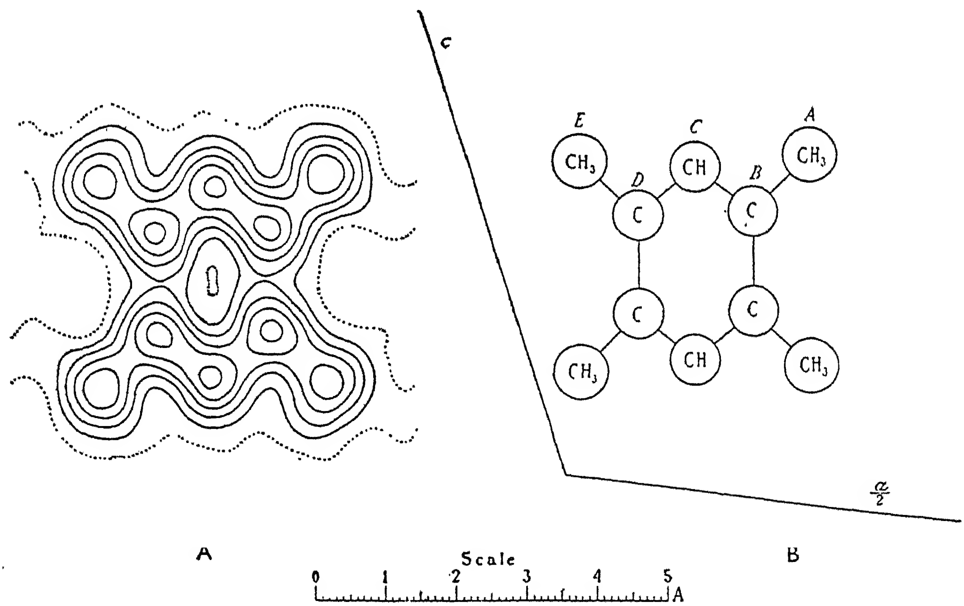

FIG. 1. DURENE (TETRAMETHYL BENZENE) PROJECTED ALONG THE B AXIS. (A) SHOWS THE DISTRIBUTION OF ELECTRON DENSITY BY FOURIER ANALYSIS AND (B) IS A DIAGRAM OF THE RELATIVE POSITIONS OF THE ATOMS IN THE STRUCTURE. EACH CONTOUR LINE REPRESENTS A DENSITY INCREMENT OF ONE ELECTRON PER SQUARE Å. IT IS FOUND THAT THE METHYL GROUPS ARE DISPLACED AWAY FROM EACH OTHER BY ABOUT 3° BEYOND THE SYMMETRICAL POSITION. THE PLANE OF THE RING IS, OF COURSE, INCLINED TO THE LINE OF PROJECTION, THUS DISTORTING IT FROM A REGULAR HEXAGON.

liquid. Sometimes clouds must overlap because atoms stand in front of one another. Sometimes one point of view is better than another: and it may happen that from all points of view an atom is difficult to disentangle. But in general as the result of a considerable quantity of arithmetical calculations we obtain projection pictures which give us a remarkably clear picture of the relative positions of the atoms of the cell, and enable us to measure distances and angles with accuracies of one or two per cent.; sometimes we can do better than that. A typical example of such a shadow picture is given in Fig. 1.[2] I will speak more fully of it later on.

It is to be observed that these shadow pictures show the disposition of the electrons which scatter the x-rays. The heavy nuclei do not affect the x-rays and the shadow pictures are silent in respect to nuclear positions. The nucleus is not necessarily at the center of the cloud, though to a first approximation at least it may generally be assumed to be there.

The x-ray analysis was first practiced about twenty years ago. Since then other important methods of measuring the physical constants of atoms have been invented and used. Some of them deal with molecules in the gaseous state; but it appears that the form of the molecule in the gas is closely related to the form in the solid, so that the information obtained is of real use in the investigation of the solid state. The x-rays themselves can also be applied, with some difficulty, to the case of a gas, and so can the more lately used electron beams. Observations of the fine structure in the infra-red spectrum give the values of the various molecular moments of inertia: the structure of the ultra-violet tells of the oscillations that take place within the molecule. From the refractive indices of gases or weak solutions it is possible to discover whether the molecule has any dipole moment, that is to say, any separation of its electrical charges, which may be permanent or induced, simple or complicated. Other information is derived from the effects of temperature, the heats of formation and so on.

In such ways a vast store of knowledge is being put together which gives insight into the details of the arrangements, composition, forms, reactions and the like, of the molecules in the solid body. It is astonishing to think of the possibilities this new knowledge is opening out to the physicist, chemist, biologist and indeed to every student of science. It is a new field of research, undreamt of not long ago. The very idea of being able to consider the properties of the individual atom was rejected in comparatively recent times by many well-known men. At a recent conference in Bonn, the president, Herr Walden-Rostock, quoted an exclamation of Schonbein's, seventy years ago: "Geht mer weg mit Eure Atome, warum gibt's nit Atome so gross wie die Leberkloss, dass mer se de Leit weise kann?"[3] (Get away with your atoms! Why aren't they as big as liver dumplings so that people can see them?)

And of course there could be no realization of the part played by the electron, before its discovery in the closing years of last century. In a discourse given in the Royal Institution in 1883[4] Lord Kelvin, then Sir William Thomson, restated a hypothesis which he had put before the Royal Society of Edinburgh twenty years before. He had then explained that cohesion might be simply a consequence of the well-known forces of gravitation. If two cubes were placed in contact and if their material were concentrated in bars parallel to the line joining their centers, and if the bars in one cube were arranged to touch the bars in the other cube at their ends, the gravi-

[2] Robertson, *Proc. Roy. Soc. A*, 142: 666, 1933.

[3] *Zeit. f. Elektrochemie*, 40: 424, 1934.

[4] *Proc. Roy. Inst.*, 10: 185, 1883.

tational attraction would be sufficient to account for cohesion provided the concentration was sufficiently intense. Thus cohesion might be due to gravitational forces whose intensity was caused by a sufficient concentration of matter in atoms or molecules which could approach each other sufficiently nearly.

We now know that we can refer the cohesion effect to forces of enormously greater power than that of gravitation. In rock salt, for example, the atoms of sodium are positively charged, and those of chlorine are negatively charged. The magnitude of the charges is that due to the transference of an electron from each sodium atom to a chlorine atom. The tremendous force due to this separation is well shown by a simple calculation suggested by Debye. If all the charged atoms of sodium in a couple of ounces of salt were placed at the North Pole, and all the charged atoms of chlorine at the South Pole, the mutual attraction would be equivalent to the weight of fifty tons! Of course such a complete separation of electricities is impracticable; more difficult than the journeys to the pole which the illustration suggests. From this example we can form an idea of the magnitude of the forces which are at the basis of physical and chemical processes. When we realize that cohesion can be ascribed to electric action, we need have no fear lest we should not have sufficient explanation of its strength. Indeed, that is really the question which I am asking you to consider. Why, if the forces are so great, are bodies not stronger than we find them to be?

But first let us see that many well-known phenomena are reasonably explained by forces of this kind and magnitude. I can, of course, deal only with a very few illustrative examples, which I will take mainly from recent investigations.

It is generally known that the new knowledge, especially that derived from x-ray analysis, has achieved very great success in the explanation of crystal structure, the external form of crystals, the existence of plane faces inclined at sharply defined and characteristic angles, the various polarities and other special properties of the different faces; it has shed light on the nature of alloys and their behavior; it has revealed the nature of the ionic crystal, like rock salt; of the crystal of organic substances in which the molecules lie self-contained and well separated from their neighbors; of the diamond, which is really one huge molecule, and so on. There is here a vast body of satisfactory agreement between experiment and theory based on the recent discoveries.

Let us take, however, a particular case which is very near to the questions we are considering. The x-rays tell us that in rock salt the atoms are drawn together by electrostatic attraction, they are held from a closer approach than the actual by repulsive forces. The work done in expanding the crystal, until the individual atoms are no longer subject to any appreciable forces from the attractions and repulsions of other atoms, can be calculated. It amounts to 182 kilogram calories for a gram-molecule of the salt. Now the necessary amount can also be found experimentally by means of a series of operations which can be carried out with great accuracy in some cases, with much less but still sufficient accuracy in others. The result is given as 181.[5] It is well to suppose that the close agreement may be accidental, but even if there were a much greater divergency, we should feel that we were in the right in ascribing the structure of rock salt to the electrical actions.

As further illustrations let me take two researches which have been carried out in the Davy Faraday Laboratory within the last few months. The first

[5] H. G. Grimm, *Handbuch der Phys.*, 24: 497, Berlin, 1926.

deals with the structure of a remarkable substance synthesized at the Woolwich Research Laboratories, and known as cyanuric triazide. It is very liable to explosion and has indeed to be handled in small quantities and with great care. Fortunately, it is possible to carry out the x-ray analysis with a crystal weighing one tenth of a milligram. The molecule contains three carbon and twelve nitrogen atoms. The absence of hydrogen atoms is a welcome feature, as their lightness makes them difficult to place by the x-ray methods. Chemical analysis shows that the three carbons and three of the nitrogens are placed at the corners of a hexagon and that three other nitrogens are attached to each carbon. These latter groups of three nitrogens each are known as triazide combinations. There has been argument as to the arrangement of the triazide group, but chemical opinion seems to have settled down lately in favor of a linear arrangement. This is confirmed by the x-ray results, as shown in Fig. 2. The upper figure shows the arrangement of the molecules and their constituent atoms drawn in agreement with the chemical and the x-ray evidence, while the lower figure is the shadow picture of electron density. The lie of the atoms is easily seen. A picture like this is very nearly the realization of the chemist's dream, that he might "see" a molecule. We see the ring of three nitrogen and three carbon atoms, and observe that it is not a perfect hexagon: its symmetry is trigonal only. The three nitrogens attached to each carbon are accurately in line. The distances that separate the centers of the nitrogen clouds are in harmony with the chemical evidence as to the nature of the bonds. The triple bond at the end of the line is drawn more tightly than any other in the molecule (Fig. 3), the double bond is next, and the single bond between the third nitrogen of the line and the carbon to which it is attached is the longest. As for the lengths of the links within the chain, three appear to be longer than the other three, which should not be surprising, as the molecule is trigonal and not hexagonal.

It is interesting that in the sodium and potassium azide crystals[6] the structure is quite different. The three nitrogens still lie in a straight line of about the same

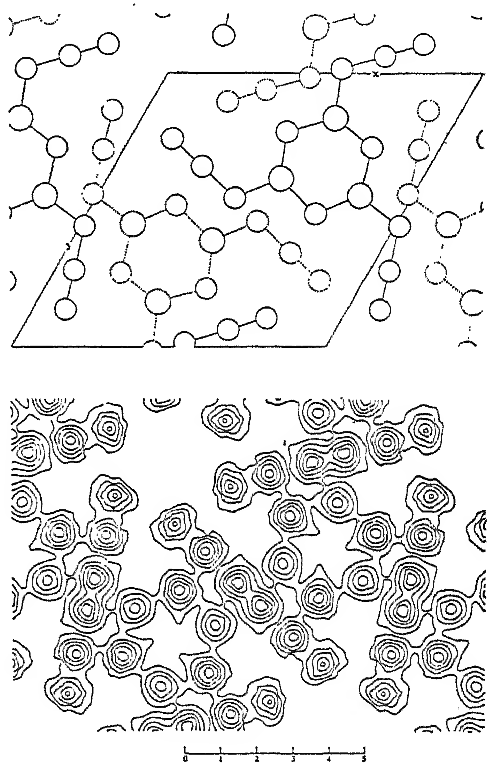

FIG. 2

length, but the group has become a negatively charged ion and the crystal is a heteropolar assemblage of positive sodium atoms and negative azide groups. The azide group is now symmetrical about its center, and the two nitrogens at the ends are at equal distances from the nitrogen in the middle. The inequality which in the cyanuric triazide

[6] Hendricks and Pauling, *Jour. Amer. Chem. Soc.*, 47: 2904, 1925.

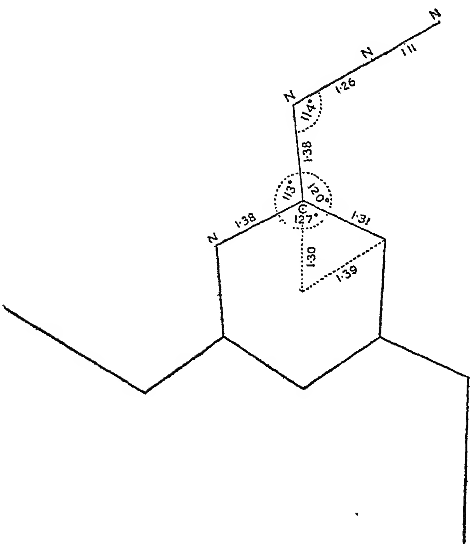

FIG. 3

marked the difference between double and triple bonds has disappeared. A similar effect is to be observed in an investigation by Dr. J. M. Robertson, to which I will refer presently.

Cyanuric triazide is a very unstable substance, exploding with great violence. This fact may well be connected with certain features of its structure. It is almost entirely composed of nitrogen. Now the nitrogen molecule is extremely difficult to break up into its constituent atoms, and a return to the molecular form is accompanied by the appearance of a large amount of free energy. Very possibly this is connected with a very close approach of the atomic centers. It has been shown that in solid nitrogen the distance apart is 1.065 Angstrom units.[7] The triple bond in Fig. 3 is marked by a distance of 1.11, and the difference is not likely to be due to experimental error. In order to form the molecule of Fig. 3 energy must be spent in breaking up the very strong bonds of nitrogen molecules. Additional energy is required to break away the necessary carbon atoms from graphite or other form of aggregation. Some of this energy is recovered in the formation of the molecule of the cyanuric triazide, but clearly there is a big balance which is recovered when the large molecule breaks up and diatomic nitrogen is formed once more.

No doubt the form of the molecule has something to do with its behavior, it looks extremely fragile, and one would expect that its "tentacles" could easily be damaged by thermal movements.

If the attachment of the triazide group to the carbon of the hexagon is broken, and attachment is made to a simple hydrogen atom instead, the resulting hydrazoic acid HN_3 is a highly explosive gas. It is curious that if the double bond is broken and attachment is made to an oxygen atom instead, the resulting nitrous acid, or laughing gas, N_2O, has no trace of explosive qualities, although it yields a considerable quantity of energy on its being broken up.

One more important feature remains to be noted. The closest distance of approach of atoms in different molecules is a little more than 3 Å. From the very first measurements of organic crystals this molecular separation has been observed and used as an aid to the analysis. The distance has not the same constancy as that which is shown by the distances between the atoms forming part of the same molecule: but it lies between 3.0

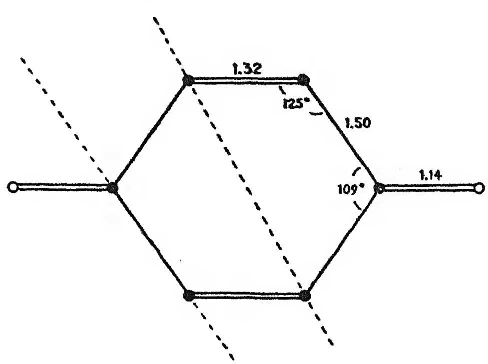

FIG. 4

[7] Vegard, *Zeits. f. Physik.*, 58: 497, 1929.

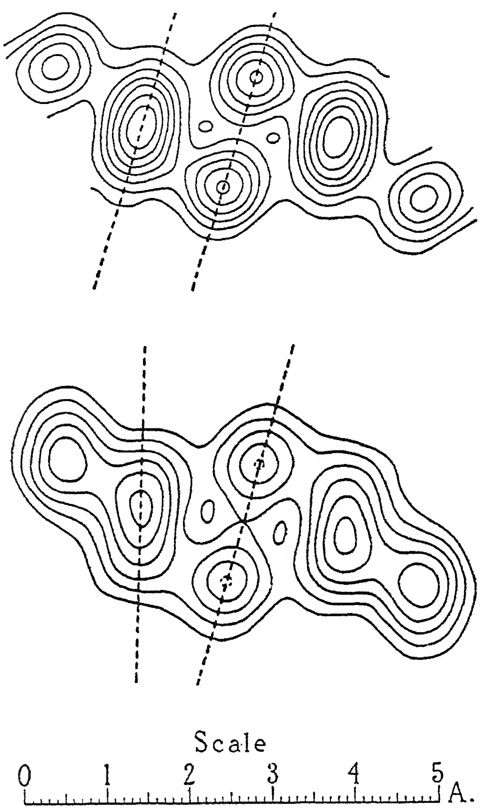

FIG. 5

and 3.5 in a very large number of cases. It is clearly connected with the extent over which the van der Waals forces are effective.

Let us now consider a second illustration, which we take from the structure of benzoquinone (Fig. 4), lately determined by Dr. J. M. Robertson. It is composed of six carbon atoms arranged hexagonally in a plane. Oxygen atoms are attached to each end of one diameter: hydrogen atoms at the other four points of the hexagon. The most notable feature is that the hexagon is not regular. If hydrogen atoms were attached at all six points the molecule would be that of benzene, and the structure would be regular, the length of each side being 1.41 Å.: this measurement has often been made and is reliable. But in benzoquinone the lengths of the sides are 1.50 and 1.32 alternately. It will be observed that the benzene value is the average of these two. This suggests a curious question. The carbon atom is tetravalent and yet in the benzene ring it is attached to three atoms only. Various suggestions have been made in order to get over the difficulty. According to one of them three of the links of the benzene ring are single bonds, the other three are double, and there is alternation so that on the average each link is the same, a mean between the single and the double bond. In diamond the bond is certainly single and is found to be 1.54. There is a double bond in benzoquinine, which has been found to be 1.32: and a value of the same order has been found from optical measurements. In the benzoquinone hexagon there is no doubt as to which bonds are single and which double. The general conclusion is that the length of the single bond is 1.50–1.54, and of the double 1.31; the side of the benzene hexagon is the mean between the two, and something equivalent to an alternation makes it so.

In Fig. 5 a shadow picture of a ring in anthracene is shown above a corresponding picture in benzoquinone; in the

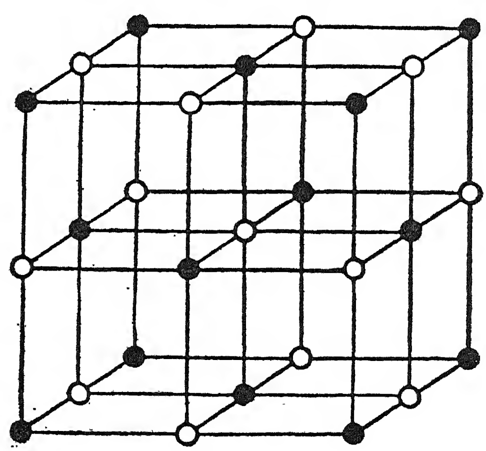

FIG. 6

one each side is parallel to a diameter, in the other it is not so.

These two determinations of structure, of cyanuric triazide and of benzoquinone will serve to show how closely we can match the determinations made by the x-ray and other new methods with the previously known properties of substances. Such a wealth of coincidence and explanation could not be sustained by a false hypothesis. It is certain, for instance, that the rock-salt construction is correct; each sodium is surrounded symmetrically by six chlorines and *vice versa*. The arrangement may be conceived by supposing the structure of Fig. 6 to be continued indefinitely in all three principal directions. Each chlorine has one more electron than its allowance when neutral, and each sodium has one less.

Suppose now that a salt crystal is ruptured by tension. The pull is applied in a direction parallel to one edge and breaks simultaneously at all points on a plane perpendicular to the line of pull. On certain assumptions, which are clearly reasonable, it is possible to calculate the force which must be applied to overcome the electrical attractions between the positives and negatives on one side of the plane of rupture, and the negatives and positives that initially faced them across the plane. It turns out to be about 200 Kg per sq. mm. If, however, we make the experiment we find that the rock salt generally gives way for a pull of less than 1 Kg. Sometimes it can be more, even much more. The strength of rock salt is greatly increased, for example, if it is tested under water, and it is affected strongly by the nature of the vapor which surrounds it. Other substances behave in the same way. What, then, is the reason of this defect? It is, of course, a matter of some concern to us because the materials which we handle might conceivably, under proper conditions, be far stronger than they are, and there might be a very great economy in the weight of constructions.

The problem very naturally presented itself as one of importance to a research worker in the Royal Aircraft Establishment at Farnborough, where the design of aeroplanes called for every possible economy in weight consistent with strength. This was Dr. A. A. Griffith, who suggested that the defect in strength was due to flaws or cracks, especially such as lie on the surface of the piece under stress. It may seem an obvious kind of suggestion, but it is to be observed that, in the first place, if there are such flaws they can not be seen under the microscope, nor can they be detected by the x-ray methods. They are too small for the one means of examination and too large for the other. In the second place, it is very difficult to account for their existence. Their amount seems to depend on the previous history of the crystal, its treatment during formation from solution, or crystallization from the melt. There are other properties which depend in the same way on the manner of growth, such, for example, as electrical conductivity, and fluorescence under radiation, so that crystals may differ widely in respect to these matters, and yet are shown by x-ray and other methods to be of exactly the same structure. Also some of these properties are greatly affected by treatment after formation. The "hardening" of certain metals and alloys by cold working is a well-known effect of great industrial importance.

There is, therefore, some characteristic of materials which causes their properties to vary, although their structure as revealed by x-rays is perfectly constant. These properties have been named "sensitive properties" by Smekal, who has studied them with great care; they are sensitive to the previous history and treatment of the crystal, while other properties such as the fine details of

structure are unaffected and "insensitive."

When this characteristic is fully understood there will be at the same time an understanding of hardening by cold working, and the rest of the sensitive properties. It is something which the x-rays do not detect, and it will probably be in accord with Griffith's hypothesis, which indeed is generally held to be correct in its essence.

The explanation suggested by Griffith is in reality based on a common experience. If a large number of small forces act in unison the joint effect may be great; otherwise their influence may be negligible. It is a very old statement that "union is strength." If the electrical forces that act across a cleavage plane of a crystal must all be broken at the same moment, the force required is very great, but if they can be taken more or less in turn the task is at any moment easier, though it takes longer to carry out. When the opposing faces are withdrawn from each other by far less than the millionth of a centimeter the attraction has practically vanished. The amount of the force as calculated is far greater than that discovered in practice because all the electrical forces are supposed to be broken at the same moment, and this, according to Griffith, does not happen. If there is a crack, the stress that should have been borne by the parts separated by the crack is shifted on to the material at the edge of the crack, which thereby experiences an excessive stress which it can not resist, and so the crack widens. When a piece of textile material is stretched it is much more likely to give way if the edges are unsound, or if the scissors are used, in the manner of the housewife, to prepare the way for rupture by making nicks in the edges. In the same way the roots of the ivy join forces until in combination, though individually they are so soft, they can lift a flagstone or tear a wall asunder. Oliver Wendell Holmes described the "deacon's shay," the parts of which were all so adjusted in mutual strength that no one by giving way threw extra strain upon the rest and led to a premature collapse. All parts lasted an equal time, and when finally the "shay" came to its end the deacon found himself seated on the road in a heap of dust.

Griffith's theory supposes that the crystal can not put out its full resistance to rupture because it is not perfectly uniform and flawless. The question then arises as to the origin of these flaws, and here there is divided opinion. Some have imagined a superstructure in the crystal, so that planes at regular intervals are weaker or at any rate different from the rest. But this conception lacks experimental and also theoretical support. A very interesting suggestion is based on the fact that crystals often grow in "dendritic" form; the accumulations of molecule to molecule stretch out into the surrounding mother liquor, like trees with boughs and subsidiary branches. Eventually the empty spaces are all filled up, and the joints may be supposed to be sufficiently imperfect to have the same effect as actual cracks. It might be that the atoms themselves, as they draw closer together when the temperature falls, find that the first arrangement into which they were cast when their motions were considerable, is no longer free from stress when their mutual and local influences can make themselves felt; and the effort to release themselves from strain may cause the appearance of discontinuities which act as flaws. Added to this uncertainty as to the origin of the flaws is a serious ignorance of the explanation of the effects of hard working. A rod of copper half an inch in diameter can be bent with the greatest ease, if it consists of a single crystal. But after it has been bent and unbent once or twice, the single crystal

is broken up into many smaller crystals and now a strong man can not bend it. Professor G. I. Taylor has alone offered a reasoned explanation of the effect; and these mysterious cracks are necessary to his calculations.

To sum up, new knowledge respecting the form and structure of molecules and their arrangement in the solid has poured forth in a flood during the last twenty years. It has provided the most interesting explanation of well-known phenomena, and this is obviously no more than an indication of what is coming. And while in so many ways it is satisfactorily linked up with experience, in others there are problems yet unsolved. The x-ray and other methods to which I have referred give a clear picture of the fine details of the crystalline structures which are the fundamentals of the solid. There is clearly a coarser structure which these methods do not touch directly. It may be regular or irregular; it may be more or less associated with some atomic property which we do not yet appreciate, or it may be quite accidental. There can be no doubt of its importance because we have so much to learn yet of the larger details of the materials which we handle and use in our constructions. Still more intricate and fascinating are the similar problems of the living organism.

RECENT ADVANCES IN INDUSTRIAL ELECTROCHEMISTRY[1]

By Professor COLIN G. FINK

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AT the time of the harnessing of part of the vast power resources at Niagara Falls forty years ago, "industrial electrochemistry" was born. Before that time the consumption of electricity in electrochemical processes was relatively insignificant. To-day the total installed electric power for electrochemical industries in the United States alone amounts to over 3,000,000 kw, a very significant figure—enough power to light a good-sized tungsten lamp in every home in the whole country. About one half of the power is required by two of the electrochemical products: aluminum metal and calcium carbide.

For many years the major electrochemical plants were segregated at Niagara Falls. To-day there are half a dozen important electrochemical centers, besides a score of smaller installations, scattered throughout the United States. Charleston, West Virginia, boasts of the largest electrolytic alkali plant of the world; at Tacoma, Washington, is one of the large copper refineries, besides two important electrolytic alkali-chlorine plants; another center is Keokuk, Iowa, with its large dam across the Mississippi; then in Montana, at Anaconda and Great Falls, there are large electrolytic zinc and copper plants, and at Massena, N. Y., the major plant of one of the aluminum companies. In most of these plants hydroelectric power is used, but steam power is competing successfully in several localities, notably in Tennessee and in California, where rates are as low as 3 mills per kwhr. Nevertheless, a number of new hydro power centers are again offering inducements to manufacturers of electrochemical products: at the new Boulder Dam, where 500,000 kw will soon be available; at Norris Dam in Tennessee; and at Coulee Dam in the State of Washington.

How are we to account for the remarkable development of the electrochemical industry within the past forty years? Why has the electrical method become the preferred one? The answer is not hard to find. The electrolytic cell turns out products such as aluminum, magnesium, beryllium and sodium that can not be produced cheaply in any other way. The electric furnace has given birth to a long series of new products previously unknown: Acheson graphite, Carborundum (silicon carbide), Alundum, calcium carbide, tungsten metal, stainless steel, "18–8" chrome-nickel steel, ferro-nickel alloys with valuable magnetic and low expansion properties, new malleable cast irons, etc. Finally, there are a number of chemical and metallurgical products that are made better, more cheaply and of more uniform quality than by the older, straight chemical methods: Thus, for example, all the copper used in the electrical industries is electrolytic copper—of uniform purity and conductivity. Then there is electrolytic zinc 99.95 per cent. pure; phosphorus made in the electric furnace; and electric carbon bisulfide, an important reagent for rayon manufacture.

NEW PRODUCTS AND NEW PROCESSES

If we confine ourselves to the last three or four years, we again record many

[1] An address delivered at the Student Convention, American Institute of Electrical Engineers, N. Y. Section. Apr. 26, 1935.

valuable additions to the long list of products and processes of the electrochemical industry. In the electric furnace field a new furnace for the production of steel direct from ore has been developed. The upper part of the furnace resembles a small shaft furnace. Reducing gases (largely CO) pass upward through this heated shaft and finely divided iron ore particles pass downward. The particles are thus reduced to metal, which drops into the electric furnace, forming the base of the shaft. Here, with the aid of the electric arc, the metal droplets are converted into high-grade steel.

The rare metal columbium is now being used in electric furnace practice as an addition to the "18–8" chrome-nickel steel to render it more easily workable.

An essential reagent used in the manufacture of artificial silk, rayon, is carbon bisulfide. E. R. Taylor's electric shaft furnace, first set up at Penn Yan, New York, forty years ago, has been improved upon. The inlet ports for sulfur vapor are located at or above the level of the electrodes and means are provided for counteracting any tendency on the part of the hot reaction zone to shift, a cause of considerable disturbance in the older types of furnace. The fundamental chemical reaction is relatively simple: Hot charcoal reacts with sulfur vapor to form carbon bisulfide: $C + 2\,S = C\,S_2$.

Another recent development of particular interest to electrical engineers is the introduction of the high frequency furnace into the steel plant. Many tons of the finest alloy steels are now made in the high frequency furnace in direct competition with the arc furnace.

In the ceramic industries the firing of the ware is still being carried out in the old-fashioned fuel-fired kiln. However, large-scale tests are now under way substituting the much more efficient electrical means of heating. Here in this country R. E. Gould, of Knoxville, Tennessee, is in charge of these tests forming part of the program of the Tennessee Valley Authority.

One of the large chemical companies has recently been largely responsible for the creation of an entirely new chemical industry. The raw materials are coke and limestone. These are fed into a large box-type electric furnace, three-phase and with three electrodes each over three feet in diameter. In the zone of the smothered arc liquid, calcium carbide is formed. After tapping this out of the furnace and allowing it to cool and solidify, it is brought into reaction with water to form the well-known acetylene gas used in welding and cutting. From this point on, the new industry develops: With the aid of catalysts, acetylene is interacted with hydrogen to form ethylene and then from this a vast variety of products—alcohols, solvents, gums, etc. —never before equaled in the history of chemistry. The new synthetic "resin" has been trade-named "vinylite." It has been made up into water tumblers, wall panels, phonograph records, floor tiles, translucent light fixtures, door knobs, denture castings, automobile steering wheels, etc.

A relatively small, yet important, new electric furnace product is cemented tungsten carbide originating in Germany but developed on an extensive scale in the United States. This carbide is used as a cutting tool and is, next to diamond, the hardest material available to industry. Practically all the oil well boring is now carried out by means of tungsten carbide in place of diamond. Furthermore, tungsten carbide tools have found world-wide application in the machine shops. It will cut the hardest steels.

Fused Electrolytes

The typical product of the fused electrolyte cell is aluminum metal; others of industrial importance are magnesium metal, sodium metal and calcium metal.

Recent additions to the commercial list are beryllium and lithium. Beryllium metal has found its chief application among the alloys. About $2\frac{1}{2}$ per cent. beryllium added to copper produces an alloy that is highly corrosion-resistant, relatively hard—like tempered spring steel—non-magnetic and non-sparking. This last property is particularly important in plants where inflammable vapors occur and where the spark of an ordinary steel tool has often caused a serious explosion. All kinds of beryllium-copper tools, chisels, scrapers, pry bars, hammers, etc., are now on the market and many thousands of beryllium-copper springs are in service to-day giving a remarkable, low-fatigue performance. Contact clips, pins and plugs for electrical appliances constitute another important application of this beryllium-copper alloy. In comparison with the older bronzes, the life of these clips and plugs has been increased tenfold.

In nature beryllium occurs widely distributed in the earth's crust. Beryl, a beryllium aluminum silicate, is the chief mineral. A relatively simple method of separating the beryllium from the other constituents of the ore has lately been worked out and is giving very satisfactory results.

Lithium metal, the other new fused salt cell product, has likewise found its chief application in the alloy field. A few tenths of 1 per cent. of lithium, together with small percentages of other elements, develops steel-like properties in aluminum. The lithium-calcium alloy is a valuable scavenger. Upon adding it to molten steel or other metal it will combine with practically all undesirable impurities.

Aluminum metal has decked itself in a new coat. Anodically-treated aluminum has resulted in a wide variety of new products, many of which are highly colored and look very attractive, especially to the modern housewife. Aluminum mirrors have replaced silver mirrors for telescopes and have been found to be superior to these—an epochal event.

The electrical engineer has become very much interested within the last two or three years in one of the older products of the fused salt cell, namely, sodium metal. This is used in the new highway or sodium arc lamp, in itself a pretty illustration of applied electrochemistry. Sodium arc lamps have been made before, thirty years ago, but they would not start automatically as the new ones do. The present development has incorporated the hot cathode of the radio tube and the gas of the neon sign. Upon closing the circuit of the new sodium arc lamp the neon gas is ionized, becomes conductive and hot, causing the sodium metal to be vaporized and ionized, and thereupon the sodium arc is established. This three-step starting of the arc results in the familiar "sun rise" effect in these new, highly efficient lamps.

Another new application of sodium metal of interest to engineers is based on its high thermal conductivity. Hollow steel sections are filled with sodium metal and used for various machine parts. Thus the valves of aeroplane motors are "sodium" cooled.

Barium metal, which has been made by the fused salt process for many years, has also found important, if not the most important, application in the electrical field. The valuable function of barium as an electron emitter and getter in vacuum tubes is well known to most readers. A spark plug company has recently reported on a nickel-barium alloy used as spark terminal. A uniform and quietly operating spark is obtained. It has been found that the introduction of barium compounds into the electric furnace arc results in a much more uniform and smoother performance of the arc.

Aqueous Electrolytes

Of greatest scientific importance was the discovery of heavy hydrogen, or

"deuterium," by Dr. H. C. Urey and associates at Columbia University. This newcomer is a product of the electrolysis of water between nickel electrodes.

In the electrolytic alkali-chlorine industry an epoch-making application of chlorine gas is charging it into sea water and liberating 10 tons of bromine per day—an important reagent in photography and in the antiknock gasoline. The large bromine plant is situated at Cape Fear, North Carolina.

In the electrolytic copper industry a noteworthy new product is the paper-thin copper sheet produced in endless lengths on a large revolving lead drum that serves as cathode. Very recently the thin copper sheet has been applied to paper and serves as an attractive wrapper for a wide variety of products.

For years the industry has been looking for a metal coating which would be resistant to the strongest of acids, muriatic, and at the same time easily applied. A short time ago we tackled this problem at Columbia University, and now with the assistance of Mr. Deren we have been able to locate and develop the desired metal coating. We have found that we can electrodeposit rhenium metal on copper, brass and steel, and in that way protect them against muriatic acid attack. Aside from industrial applications rhenium plate is of special interest to jewelry manufacturers. Wrist bands which are rhenium-plated resist the attack of the acids in perspiration. Chromium, rhodium and even silver are attacked by perspiration, whereas rhenium is not. Rhenium plate is remarkably free from pinholes, does not tarnish nor smudge. The present source of rhenium metal are the slimes of one of the large electrolytic copper refineries. These copper cell slimes have given rise to a number of industries. Thus selenium, an essential metal in many of our modern photoelectric devices, is extracted from these slimes. Selenium and its sister metal, tellurium, are now being regularly recovered at electrolytic copper and electrolytic nickel plants. Tellurium is an important reagent in the electrolytic zinc industry.

Several laboratories have devoted considerable effort to the electrodeposition of alloys. The Bell Laboratories have electrodeposited magnetic alloys composed of iron, nickel and cobalt. At the University of Minnesota Messrs. C. L. Faust and G. H. Montillon have developed a process for the deposition of nickel brasses. Brass as such has been commercially deposited on steel for the last fifteen years. At Columbia University we have been depositing a silver-white corrosion-resistant alloy of cobalt and nickel; also a highly acid-resistant alloy of silver and lead, and another of tungsten and palladium. This field is a most fascinating one and offers great possibilities. The mechanical preparation of thin alloy sheets is often very difficult and tedious, whereas the electrodeposition of such sheets is usually relatively simple.

Electrochemistry of Gases

Of all branches of electrochemistry that concerned with the discharge of electricity through gases is the most fascinating. However, due to the greater ease in handling solids and solutions, investigators usually avoid this branch of the science. From a practical point of view a number of circumstances have in recent years contributed toward a better acquaintance on the part of the engineer with gas reactions, gas transportation, gas recovery and generation, etc. Thus the use of gases in welding and cutting, gases in warfare, neon and other gases in electric signs, ozone generators, Cottrell precipitators, gas arcs, etc., have all helped to bring about a decided change in attitude on the part of the engineer. From an industrial point of view the recent developments in the sodium vapor and high-pressure mercury vapor arcs deserve special mention. Important,

too, are the researches of Dr. S. C. Lind at the University of Minnesota on various gas reactions initiated by radium emanations; and the researches of the Fixed Nitrogen Research Laboratory at Washington, D. C., under the direction of Dr. F. G. Cottrell on electrical methods of synthesizing nitric oxide. Electrical engineers will recall that in the corona discharge nitrogen is more readily ionized than oxygen—quite contrary to our early suppositions.

Many Unsolved Problems in Electrochemistry

Young students desirous of taking up a research problem often feel that "everything has been solved." This is far from the truth. Every new product or new process gives rise to a dozen new problems. The discovery of high frequency induction melting of steel and the appreciation of its commercial possibilities happened years before the first large furnace was in successful operation in the steel plant, and the delay was largely due to the many problems that had to be solved before the basic discovery was adaptable commercially.

Opportunities are greater than ever before and the possible new discoveries are unlimited in every branch of electrochemistry. We need an electric furnace that will easily and efficiently convert ores into finished metal products; we need a new process for the production of aluminum metal, one that is much simpler and cheaper than the present one; we must further develop the photovoltaic cell so that it will readily convert large blocks of sun power into electric power; we need strong, low-density alloys that have a fatigue resistance equal to that of steel; we must find a simple means of electrically controlling and directing rainfall—keeping it out of the cities; we need, most urgently, a simple but efficient method of protecting steel products and steel structures against corrosion and thus save many millions of dollars now lost; we must find an electric source of illumination suitable to our eyes that will operate at 90 per cent. and better in efficiency instead of less than 10 per cent., as at present; we are trying to find an electric heating unit that will operate a thousand hours or more in air at temperatures of 2,000° C. (3,600° F.) or above; we must find a simple process of producing large ingots of malleable titanium metal, one of the most prevalent constituents of the earth's crust (6,000 times as abundant as lead); we should systematically investigate the application of electric currents in the stimulation of the growth of living cells and the formation of many important organic compounds; we must find and develop dielectrics free from the shortcomings of the many in use to-day; we need hundreds of new products difficult or impossible to discover during the countless ages of the past with mechanical skill alone, but to-day readily possible through the combined power of electricity and chemistry. Truly the young electrical engineer looking for "worlds to conquer" will do well to survey the vast but little-explored domains of electrochemistry.

WHAT CAN YOU DO WITH YOUR NOSE?

By Dr. DONALD A. LAIRD

DIRECTOR, COLGATE UNIVERSITY PSYCHOLOGICAL LABORATORY

ROMANCERS of the dear, gone days usually concede the passing of the fine art of conversation and the fine art of smelling. Even our contemporary psychologists, with dignified aplomb, casually pass by the sense of smell as something that is notable among animals but sadly deficient in mankind. The scientific study of the sense of smell in man is in truth sadly deficient, but man's sense of smell is not the degenerated nor inconsequent power that is often alleged. Scientific neglect has made it mistakenly appear that this oldest of our senses is itself neglectful.

Our sense of smell ten years ago was just as keen and capable of as many discriminations as any of our other senses, according to the late Edward Bradford Titchener, who led in knowledge of the psychology of the senses. Professor Titchener could find no basis in fact for the belief that this is a degenerating nor useless sense. True, "the olfactory sense is the master guiding stimulus in all lower animals," as Professor Frederic Wood Jones, of the University of Hawaii, observes, while in mankind it merely is not so overwhelmingly prepotent.

The sense of smell determines much more of our behavior than we like to admit, or than we consciously realize. Take the simple matter, for instance, of unexpected notions or recollections popping into our thoughts. What stimulated these recalls? Even a good introspecter is unable to trace some of them to the stimulus that precipitated the rush of long dormant scenes and actions.

It is now shown that these memories of the past that have a peculiarly haunting, emotional grip over us are often aroused by some fleeting odor. Harvey B. Fitz-Gerald, working in the Colgate Psychological Laboratory, has recently made a close study of odors as revivers of memories and provokers of thoughts in 254 living men and women of eminence. Our group of collaborators in obtaining the data averaged 52½ years of age. More than four out of five of them reported to us many experiences similar to this one of Dr. Walter E. Bundy:

> The smell of fresh sawdust invariably takes me back to the sawmill where my father worked when I was a small boy. The sight of sawdust does not call up these boyhood memories, but the odor of fresh sawdust never fails to reconstruct a series of vivid pictures so graphic that for the moment I live the scenes again. If I try to reconstruct these memories of the sawmill by conscious mental effort, I can locate this object and that, this person and that, in the scene, but the memory thus constructed lacks life and is hazy. But the odor of fresh sawdust, especially when the odor reveals its presence, before I have seen the sawdust, calls up the whole picture as real as life itself.
>
> For a period of twenty years I had noticed the fact that special odors call up special memories, and always the same odor produces the same picture. Sometimes I have been actually startled by a long-forgotten picture popping into my mind, and it was called up by some peculiar odor. No memory stimulus breaks my train of thought so abruptly and completely, transports me through the past so rapidly to some remote scene, as a proper quality of odor.

Some had never given conscious notice to this interesting power of smells in reviving vivid memories, but when it was called to their attention in our inquiry they were overwhelmed with this striking phenomenon. Typical of these is this report from William S. Dutton, the writer:

Until your inquiry, I was not consciously aware of odors arousing memories in my case. Study of the matter since has uncovered the fact that the mere thought of a particular odor immediately revives some incident out of the past, of a varied nature but mostly pleasurable. I am also aware now that odors have been prodding my memory possibly throughout my life.

However, name to me almost any odor and at once it recalls something from the past. As I test myself, I revive a world of seemingly forgotten things and realize that odors have been keeping those things alive in my head for many a year. It seems significant that none of these memories are of very recent origin—the latest, after some experimenting, is ten years old. I wonder if the odors of today will be jogging memory ten or twenty years hence, or whether the oldest memories will continue to keep the front of the stage?

At the other extreme were those few with whom this occurrence was so commonplace and so recurrent that they had taken it for granted. Horace J. Bridges, the Chicago author, thus portrays the commonplaceness of it with him:

My only difficulty in replying to the questions is just the fact that, with me, the revival of dormant memories ("forgotten" things) by stimulation of the sense of smell is so common, has occurred and been observed so many times, that I have long since abandoned any attempt to keep track of them. I suspect this to be the case with many people, who themselves don't trace the association factor.

The fact is, having long since come to the conclusion that in my particular case the sense of smell is an especially effective memory-stimulus, I have accepted it and ceased to note down particular cases.

A Cornell University chemist nearing seventy reported "association of odors with past events so common with me that no especial attention has ever been paid to the phenomenon." One wonders whether his occupation as chemist may have made him unusually disposed in this way, or whether a natural bent along this line helped qualify him for a distinguished career in the field of chemistry.

Observations of such experiences are by no means rare, as the following tabulation shows:

	Women	Men
	Per cent.	Per cent.
Reporting many such observations	71.2	63.5
One or two such experiences	20.5	16.0
No such experiences recalled	8.2	20.4

Not only are these experiences common to the general run of mankind, but they appear from these data to be significantly more frequent with women—which may throw light on the feminine favor for perfumes and aromatic flowers and herbs. Truly, the sense of smell may not dominate our mental lives so exclusively as it does the lives of our animal friends, but it is obviously not a sense neglected in our storing and recollection of life's joys.

It is possible that the prominence of smell-linked memories varies in different sections of the country. Our data are not large enough to separate them into sections, but the thought is intriguing and may have some reasonable basis. The plant pathologist, James Greenlief Brown, now residing in Arizona, is one of several who have suggested this. He communicates to us:

In this dry climate, both pleasant odors and unpleasant odors are much less marked than in moister climes. I believe that you would find mental associations connected with odor much less prevalent in persons who have lived in a dry climate during a part,—the early part, of their lives.

A California attorney, somewhat disloyal to his adopted state, and perhaps best unnamed, has also observed territorial differences. He reports:

I grew up on the Nevada desert in a small mining town. Since my seventeenth year my residence has been in California in the San Francisco bay area but I never have and never

will learn to be happy in the fog and rain and dampness. I have a perpetual nostalgia for the sun, warmth, clear, clean air, the peculiar lemon desert fragrances and the great panoramic vistas and strong colors. I have spent part of several summers in the Tahoe district and each time have brought home a good bunch of sage brush which I keep in a receptacle and not infrequently smell. When I do, visual and emotional sensations arise within me in considerable clarity of the desert scene. A slight sniff doubles and redoubles that tranquil nostalgia.

Of more lasting significance than these interesting conjectures, however, and even perhaps transcending the astonishing frequency and commonness of smell stimulated memories, is their dynamic rôle in our activities.

These memories revived by passing fragrances are, by and large, very vivid memories, and not just casual will-o'-the-wisps in our mental fabric. That these smell-revived memories are among their most vivid memories is attested by 76 per cent. of the women and by 46.8 per cent. of the men; only 4 per cent. of women and 6 per cent. of men reported that these memories were of less than average vividness. Again we notice a more marked rôle in woman's mental life.

Odor-stimulated memories are emotional memories, as well as vivid memories—possibly the one causes the other. Only 7 per cent. of the women and 16 per cent. of men—that sex difference persists!—report that the memories thus revived are neutral, neither pleasant nor unpleasant. Little trouble, now, to comprehend the potent part played by these in human behavior, and a pleasurable part, in general, since the pleasurable vastly dominates in the experiences recalled by passing environmental odors.

At times, it is true, it is a painful pleasurableness, a wistful longing but still pleasurable in the main. Listen to these brief accounts to gain some conception of the vividness and emotional power of these recalled experiences which we owe to occasional whiffs brought to our nostrils by stray air currents:

One afternoon at the age of twenty-five while reading a book a very strange sense of *loneliness* came over me. Various memories of my childhood came up before me, especially the memory of books that I had read as a child. I looked the book over very carefully and could find no reason for this sudden recall. The print of the book had a strange pleasant odor. I turned to the front of the book and found that it had been printed in London. I have since found that English and American print have very different odors. Several times since then I have had this same experience and when turning to the front of the book have found that it was printed in London. As a child my books all came from England. Odors play a very important rôle in my life. Under nervous strain I have found that perfume brings relaxation and at night will put me to sleep.

How these stray fragrances may precipitate, through their emotionally tinged recollections, possession by a mood or the blues, is shown by this instance:

On the train once, in the midst of happy conditions, I suddenly felt discouraged, awkward, unhappy. As soon as I recognized the perfume used by a fellow traveler, I saw very vividly a large dancing class, a French dancing master, and felt again my girlish dismay at his attitude toward my poor attempts to learn the steps he was trying to teach me. As soon as the memory-picture came I knew why I had suddenly felt unhappy, and, of course, came back to normal. This experience occurred some fifteen or twenty years after the last time I had seen the dancing master.

Here are some additional experiences which illustrate other angles of the emotional power of these odor-stimulated memories or states; they are obviously more than a mere memory—fused with simple memory of the past which rushes over one is a poignancy, a longing, a wistful desire.

One woman author reports:

In reflecting on my own experience of the relation of odor to memory, I should say that

the most vivid memory evoked is the memory of emotion experienced during the period of time with which the odor is entangled. For instance, lilacs to me revive a general memory of the years from twelve to eighteen, particularly the emotional flavor of those years, with a great deal of its intensity. This vivid recollection of emotion does not come otherwise, except occasionally in dreams.

A southern attorney tells us:

The sight of these things sometimes occasions the recalling of the facts but they come shapeless and indistinct—dead facts. The thing that is recalled by odor comes unasked and without effort upon my part; it seems more than a mere recollection; I am back there again in a world as it was and I am as I was.

A New York statistician has noted the all-inclusiveness of these recalls, as follows:

All my life I have found odors to be the most vivid stimuli to recollection and the things recalled are not clearly delineated pictorially but they are reproductions of prior states of mind that accompanied the original sensory experience.

The paralyzing, albeit pleasurable, power of these revived states of mind is indicated in this account from an eastern inventor:

When ten to thirteen years of age I had much to do with horses and stables. Then nothing. At twenty years of age I one day was walking along a country road, and a cart, laden with stable manure, was some 100 yards in front of me. The odor caused a sudden shock of memory of the years of my childhood, which thrilled me into *immobility.* Since then the reaction has been experienced several times but only in a mild degree. The first time it quite shocked me—that is thrilled me, so that I stopped in my tracks for a brief moment.

This deep-seated organic reverberation, perhaps reflecting mankind's primordial dependence upon olfactory senses for protection, is interestingly described as follows by a University of Wisconsin chemist:

Certain odors connected with the out-of-doors have a tremendous emotional potency with me—and produce a pleasurable response—almost like a chill in vividness. Most of them date far back to my earliest definite recollections.

Dated back to earliest definite recollections suggests that the part played by the sense of smell is lasting and well-nigh permanent. It will be recalled that the average age of our group of 254 persons was 52½ years. The average age at which the earliest smell-revived experience took place was 16½—indicating a minimum average span of at least 36 years. Many, of course, are much older. An Episcopal dean of the south, for instance, has odor-revived memories more than 60 years old. A Connecticut insurance executive, now 73 years of age, was recently carried back by these to his fourth year, to the time of the occupation of Norfolk.

It is not possible to set a span of years for the average life of these, for, as many of our informers report, "it is a continuous process." Not just a few episodes are subject to this interesting phenomenon, as the instances presented for illustration might suggest, but new experiences are being continually added to the store subject primarily to olfactory recall.

Ellis Parker Butler, for instance, summarizes his experience in this way:

The odor of wool brings a picture of my Uncle Lem who died when I was a very small boy—perhaps because he had a new and "wooly" overcoat, having just set up as a doctor.

A mere "whiff," of small intensity and instantaneous in duration, is sufficient to arouse a connected memory in my case. Probably this is true in most cases. An "odor memory" can be destroyed—at least for a while—by "reconditioning" the sense to a new connection. For example: A friend buys a new wooly overcoat that smells of black dye. The first whiff of the wool-dye odor brings back my Uncle Lem. In a few days the wool-dye odor means the friend with the new overcoat and no longer reminds me of Uncle Lem. For a while any wool-dye odor reminds me of the friend. A year or so later the original memory stimulus returns—

wool-dye again means my Uncle Lem; the friend odor has become a pipe, a cigarette or some other thing. Still later the wool-dye odor with certain other factors brings back Uncle Lem, but with still other factors brings a memory of the friend.

In this way, if an odor is encountered very frequently (as, say, Turkish cigarette odor) the connected memories are so numerous that they cancel each other by confusion, but in the long run it is always the pleasantest or unpleasantest connected memory that is evoked by the odor, and this is usually the earliest connection. I believe that men of my age and older are especially apt to the recall of early memories through odor associations, because the interim associations have become so numerous that they are lumped and ignored.

Age may bring about changes. Several of our correspondents have noted this, and it is likely due in part to a decrease in olfactory acuity, along with the dimming of the other senses, with gaining age. But youth is no stranger to this rôle of the nose. Take the five-year-old girl in Massachusetts who frequently says, "This smell makes me think of," and she tells what happening it does make her think of.

Can this be a sense which educators have overlooked as an avenue into the mind? Or one that advertisers should cultivate in their copy and product? Certainly, it is not neglected by the tentacles of the individual's mental life, nor with its common occurrence, its vivid revival, all-pervading emotional quality and its cause of sudden shift of mood and fancy.

It will be found interesting, the next time an unexpected memory or thought "pops into your head," or when you can not account for a mood which, we hope, may be quickly passing, to think back over the air-borne fragrances and odors which may have given these changes their start. For, as a mid-western bishop summarized his accounts to us: "Smell is sure some automatic reminder."

THE POORHOUSE OF THE UNITED STATES

By Dr. EARL B. SHAW
STATE TEACHERS COLLEGE, WORCESTER, MASS.

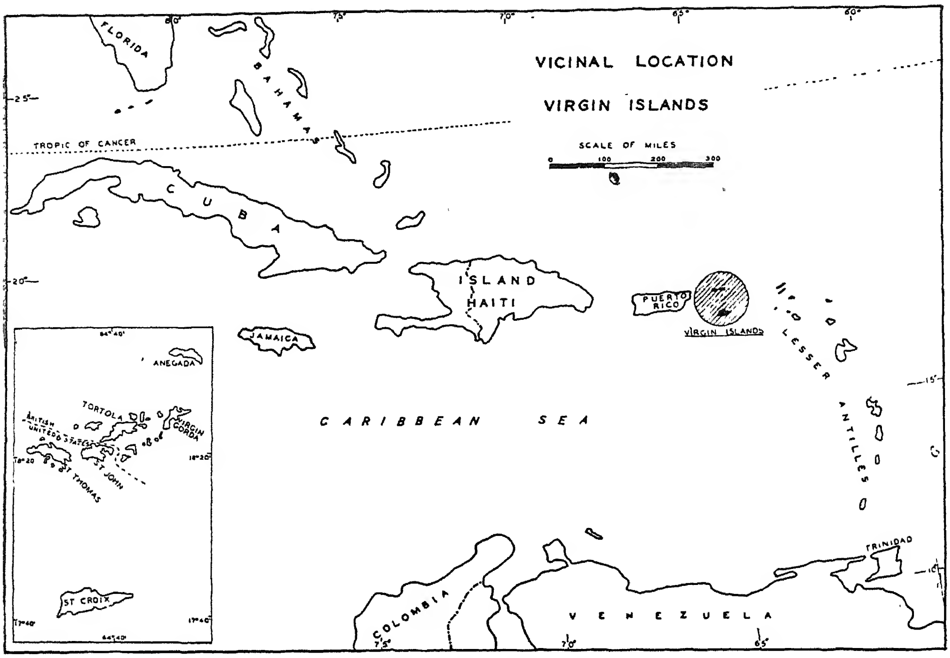
WHEN Herbert Hoover visited the Virgin Islands of the United States in 1931, he was not favorably impressed with them. In fact, his impression was so adverse that he gave to Uncle Sam's farthest east possessions in the Atlantic a name which has clung to them ever since, a name which offended native Virgin Islanders and a name which received wide publicity throughout the United States. Mr. Hoover called the Virgin Islands an "effective poorhouse." There seems little doubt that the distinguished visitor was untactful in giving his thoughts such candid expression, yet just how far from the truth is this objectionable nickname? Was Hoover justified in even thinking such a thing? The writer believes that the ex-President was justified and will attempt to show by an analysis of the Virgin Islands' resources that, from an economic standpoint, the islands are a liability rather than an asset. He will also suggest how the investment may be viewed optimistically if debits and credits are written on another balance sheet.

The Virgin Islands of the United States, St. Croix, St. Thomas and St. John, together with about fifty adjacent islets and cays, most of which are uninhabited, form a northeastern outpost in the Caribbean Sea. Forty miles east of Puerto Rico and a thousand miles northeast of the Panama Canal, they lie 1,400 miles southeast of New York. They are rugged volcanic islands, with an area about twice that of the District of Columbia and a predominantly colored population of approximately 22,000 people.

The United States paid Denmark $25,000,000 for the islands in 1917. This is more than $295 an acre, a high price compared with two cents an acre for Alaska, less than three cents an acre for California, Nevada, Colorado and Utah, approximately four cents an acre for the Louisiana Purchase, less than fourteen cents an acre for the Philippines, and but $35.80 an acre for the Canal Zone. In view of this fact, the physical environment of the islands merits a study which will determine the possibility of payment of dividends upon such an investment.

More than a century ago prosperity reigned in the Virgin Islands. Danish colonists planted sugar cane when they first made permanent settlements, prior to 1700, and from that day to this, although the industry has passed through many vicissitudes, sugar has remained the major crop. When Europe was paying high prices for the luxury and Negro slaves from the Guinea Coast of Africa afforded cheap labor, planters made large profits, and their scale of living was as high as any existing in the world. Ruins of the old "great houses" scattered about the islands still yield bits of imported marble from the tesselated floors. However, the expansion of sugar-beet-growing in temperate regions and of cane production in the East Indies and the liberation of slaves in the Virgin Islands put an end to this easy profit by the middle of the nineteenth century. On the two more rugged islands where machine culture was impossible, fields reverted to grass or forest.

St. Croix, which has a fertile limestone plain between the volcanic hills at either end, suffered less than her sister isles. Planters began to practice machine cultivation and to substitute centrals for the



VICINAL LOCATION OF THE VIRGIN ISLANDS

wind-and-animal driven mills whose strongly constructed gray stone frames stand like sentinels throughout the island to-day. Because of these changes, the industry continued to bring profits to the St. Croix planter in years of favorable rainfall or high prices, but suffered severe losses in the event that either of these conditions failed. Since the beginning of the twentieth century, competition from sugar produced more cheaply in Cuba, Puerto Rico, Hawaii, Java and the Philippines has caused a decline of more than 50 per cent. in the sugar acreage.

The great limiting factor which prevents the success of sugar in St. Croix is rainfall. Because of the drying effect of the trade winds, there must be at least forty-five inches of rain, well distributed through the year, to give even a fair yield of cane. In only half of the eighty years of weather records has the total been as great as this, and in 1873 less than thirty inches fell. Not only is the annual total uncertain, but distribution as well. In some years as a result of tropical hurricanes, one-fourth to one-third of the entire precipitation may fall in a single month and the remainder be insufficient for a good cane crop, even though the amount for the year is high. In general, sugar production in St. Croix rises and falls with the annual rainfall, in contrast to production in Cuba, where rain during the growing season is far more dependable.

The use of deep wells or reservoirs to obtain water for irrigation of the cane, as in other countries of deficient rainfall, does not seem feasible in St. Croix. The small size of drainage basins and flatness of river valleys which might be flooded make reservoirs impracticable. The inflowing water to be stored would not always be adequate, and the evaporating surface would be so large in proportion to depth that the supply would be further diminished. Geologists report adversely upon the possibility of deep wells, and even the most optimistic consider that water obtained thus could in-

crease the moisture available for sugar cane by only 10 per cent. of the total precipitation.

Goods and passengers enter and leave St. Croix by lighter from ocean vessels which lie at anchor some distance beyond the coastwise shallows. This constitutes a marked disadvantage to the sugar industry by adding to the cost of transportation; it is more expensive, of course, to lighter sugar to the ship than to load it at the dock. It is also more costly to operate small sugar centrals than to run large ones; and those of St. Croix have a capacity of approximately thirty thousand tons of cane a season, in contrast to some in Cuba and Puerto Rico which grind eight to ten thousand tons a single day. There is thus a high overhead charge in manufacture which forms a further drawback to the industry.

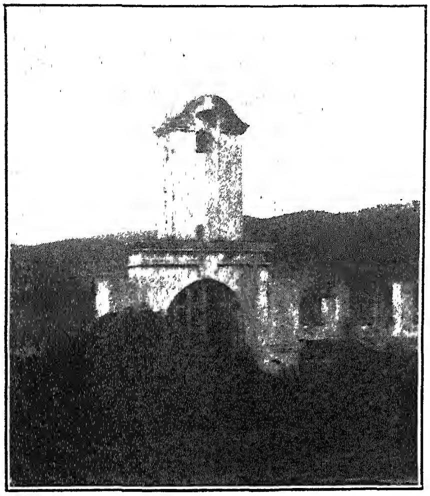
The boon of tariff-free entrance to continental United States, the world's greatest sugar market, only partially compensates for the long list of handicaps to sugar production in St. Croix. Although the industry has survived by means of this prop, it is literally losing ground in the struggle, for in the past fifteen years field after field of sugar cane has been abandoned or allowed to grow up to grass, which is being used for pasture.

Throughout the Virgin Islands it is possible to maintain natural and improved grasses suitable for pasturage. While rainfall is too scant for good forest and relief, with the exception of St. Croix's coastal plain, too rugged for cultivated crops, both factors favor a vegetation upon which cattle thrive. Water is available in shallow wells except in times of extreme drouth, the animals need no shelter against cold, and furthermore there is a market for beef in the nearby crowded island of Puerto Rico. With these advantages the industry ranks a close second to sugar in St. Croix and is the dominant agricultural activity in the other islands. There are, however, distinct handicaps to cattle raising which preclude the possibility of its forming the basis of prosperity. During the dry season the parched grasses are not nutritious, and scenes in years of severe drouth show lean and half-starved cattle vainly endeavoring to snatch a living from leaves and twigs, while bones protrude so conspicuously that a hat could almost be hung on portions of a cow's frame. Ticks and fever form an ever-present menace. Calves, gaunt and wobbly, gave the writer a vivid impression of the seriousness of this malady. Even without the environmental handicaps, the industry could never benefit the islands significantly, because it employs such a small number of people. Although at present cattle raising occupies 80 per cent. of the land, it gives employment to only 3 per cent. of the labor.

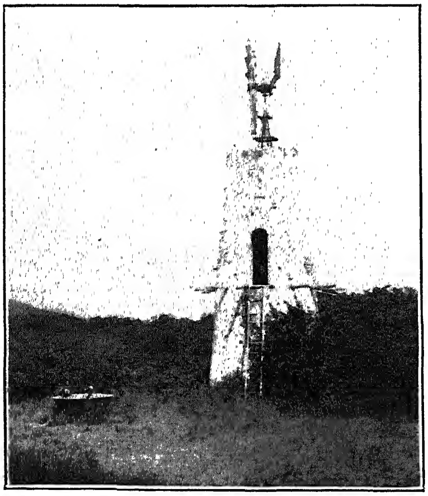
Cotton, which would undoubtedly be a great boon to St. Croix, has been suggested as a substitute for the declining sugar. This crop, which thrives under the rainfall régime of the island, could not only be grown by renters on small plots of land unsuited to cane, but would fit into a rotation system with the sugar cane itself. The fiber would provide an outlet for much of the idle labor and increase the revenue of the people as a whole. Yet the plant can not be grown successfully because of the pink boll worm, whose eradication seems almost impossible. Even if possible, reinfestation from nearby islands or through commercial channels would be almost certain, as the insect has a considerable flight range and no quarantine service is maintained for small inter-island boats.

Vegetables are also a possibility. Again, most physical features are favorable; for machines may be used on the flat rich earth of St. Croix, most of the rain falls during the growing period from September to January, labor is plentiful, and the crops ripen at a time when the manufacturing centers of northeastern United States are demand-

ing a fresh product which can not at that season be raised near the market. Although no frost occurs and the major growth of vegetables comes after the hurricane period, one serious climatic handicap stifles the industry. The uncertainty of the rains frequently results in late planting and delays the harvest until the northern market is flooded by producers in continental United States. Furthermore, insect pests and plant diseases are rife. The writer was impressed by this fact while observing growing corn at the St. Croix Experiment Station. He remarked to the attendant that the few rows looked almost as healthy as the big fields of the Corn Belt. "Yes, that's true," replied the gardener, "but if you knew how much and how many times insecticide was applied, you'd realize how expensive it is to bring those plants to maturity." In addition to such difficulties transportation facilities are inadequate.



BELL TOWER ON PROSPERITY ESTATE
THE BELL TOWER, RECENTLY REMOVED, IS A REMINDER OF SLAVERY DAYS. THE PEAL OF THE BELL CALLED THE NEGROES FROM WORK IN THE CANE FIELDS.



THE OLD AND THE NEW
A WINDMILL ON THE FRAME OF AN OLD STONE SUGAR MILL. TO THE LEFT IS AN IRON KETTLE WHICH, MANY YEARS AGO, WAS USED FOR BOILING SUGAR AND NOW SERVES AS A WATERING TANK FOR CATTLE.

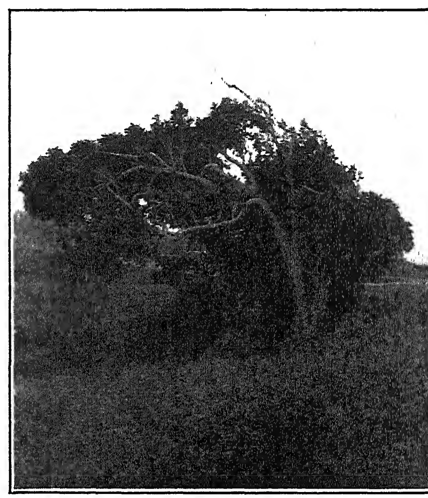
Although St. Thomas was once famous for its shipping, relatively few vessels call there to-day. Frequent service could now be attracted only by a large-scale development of some industry, but such a change seems unlikely. In the days of New World dominance by Spain, pirates hid in St. Thomas' bays and harbors to prey upon Spanish treasure ships assembling there before making the last long leg of the trip to Europe from the West Indies and the Spanish Main. Later the strategically located harbor on the southern coast gained fame as an entrepôt for West Indian trade, and at a still later date, when steamships not only entered West Indian ports directly but carried whole cargoes, obviating the need of an entrepot, St. Thomas became a coaling station for these vessels. To-day, however, its importance has declined tremendously. With the competition of Panama Canal ports and the greater steaming radius of ships using fuel oil, the fueling business is no longer as important, while it is many years since food, water or orders from home have necessitated calls at the port. Moreover, since the transfer of the islands from Denmark to the United States in 1917, the Ham-

burg-American Line has established its terminus at Curaçao; and St. Thomas, which before the war monthly accommodated sixteen of the German ships at its docks, has lost not only the trade they brought but the employment they furnished to a thousand stevedores in loading coal and cargo. Although there has been no serious decline since the United States obtained control, the shipping is now almost entirely connected with bunkering, and has comparatively little effect upon local business and employment in the Virgin Islands.

Two other industries associated with the islands are lumbering and the manufacture of bay rum. Mahogany trees which supplied material that may still be found throughout the islands in the rich brown tables, four-poster beds and massive desks, would indeed be an asset to both the islander and the lover of beautiful furniture in the United States. Some believe that valuable stands of such timber could be raised, but actual tests by a government forester show that physical limitations, particularly drouth and hurricanes, are great. Even should trees be grown successfully, the limited market and lack of shipping facilities would prevent successful competition with more favored areas. The large acreage necessary and the length of time involved in growing a tree crop make private land-owners unwilling to cooperate in reforestation. The bay rum industry, in which the bay oil of St. John and the alcohol by-product of St. Croix sugar meet at St. Thomas for manufacture, has increased from 10,000 gallons in 1910 to 138,000 gallons in 1931, and is one of the important industries, yet it provides employment for only seventeen workers.

Fishing, to which some people have turned for lack of other occupation, is similarly destined to a small future. Although surrounding banks abound with fish, types suitable for canning are present in insufficient quantities for export. The limitations to agriculture, forestry, shipping and fishing are paralleled by a lack of basic raw materials for manufacture. With no coal, petroleum, water power, iron or timber, there is little possibility for industrial development. The Virgin Islands do have a supply of labor, inefficient though it may be, and there exists a possibility of small-scale activity in textiles, furniture, toys and basketry.

Although the background of the Virgin Islands definitely limits much revenue, they serve well as a funnel into



TREE BENT BY THE WIND

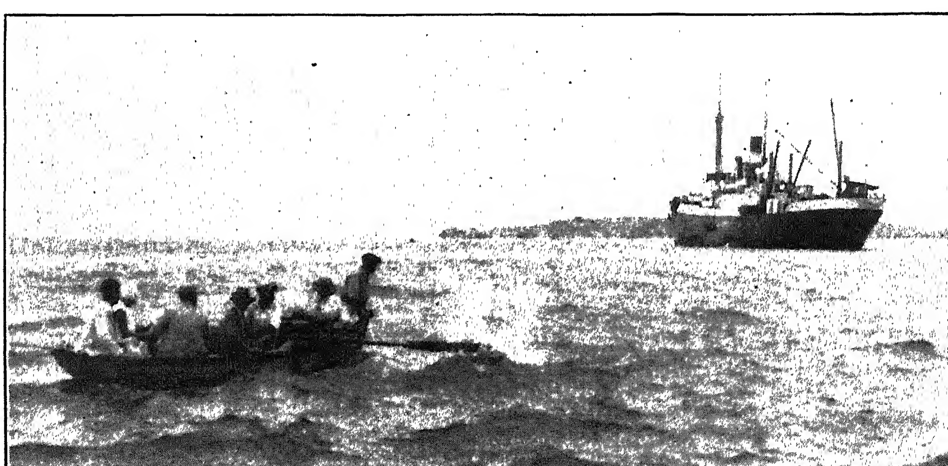
THIS TREE IS A GOOD INDICATION OF THE STRENGTH AND CONSISTENT DIRECTION OF THE TRADE WINDS IN ST. CROIX.

which federal funds may be poured. Since the purchase by the United States the nation has contributed funds amounting to several hundred thousand dollars each year for their upkeep.

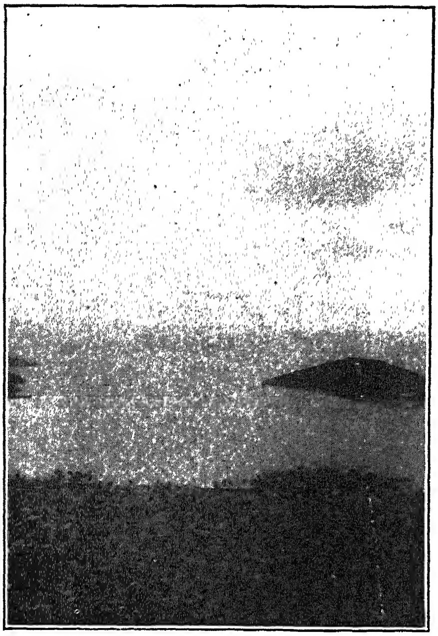
The cost of governing these three small islands of 132 square miles, an area only one-eighth as large as an average-sized county in Texas and containing a population but one-tenth as large as Worcester, Massachusetts, is entirely too high. There is a governor, lieutenant-

governor, finance commissioner, commissioner of public works and a commissioner of industry. There are colonial councils and judges, various boards and a whole retinue of governing officials, all for the government of 22,012 people. Surely economies in government could be effected. For example, would it be impossible for one governor and a governor's staff to perform the duties of that office for both Puerto Rico and the Virgin Islands and thus dispense with several thousands of federal outlay? Of course the tropics are not conducive to excessive physical or mental effort on the part of the white race, but it is doubtful that the added duties coincident upon such a change would injure the health of the governor of the two possessions.

But the Virgins would fight such a change; for an exaggerated sense of individualism is a characteristic aspect of the life here as well as on most islands in the Lesser Antilles. Dr. Whitbeck, of the University of Wisconsin, uses the Lesser Antillean possessions of Great Britain to illustrate this point. "Again and again efforts have been made to group the islands, reduce the number of separate governmental units and thus reduce the number of major officials and the high cost of government. . . . The best that the mother country has been able to do is to restrict the insular colonial units in these waters to four colonial governments each having a governor sent out from England. . . . The entire area of three of these units is only fourteen hundred square miles, or two average midwestern counties of the United States. The governor of each of these small colonies is expected to be a 'Sir' and usually a lieutenant colonel or colonel. He lives in a spacious mansion surrounded by servants, is treated with more respect than a governor of our Empire State, and is paid a salary of twelve thousand to twenty thousand dollars a year. . . . It has been relatively easy to unite the provinces of Canada into a single dominion of continental size, but the island peoples of the British Antilles refuse to be united. It is a case of insular psychology gone mad, yet when any proposal to unite these subunits or units is made it meets with determined opposition. Each island's slogan seems to be 'Whom God hath put asunder let not man join together.' " Attempts at uniting the government of Puerto Rico and that of the Virgin Islands would meet the same slogan.

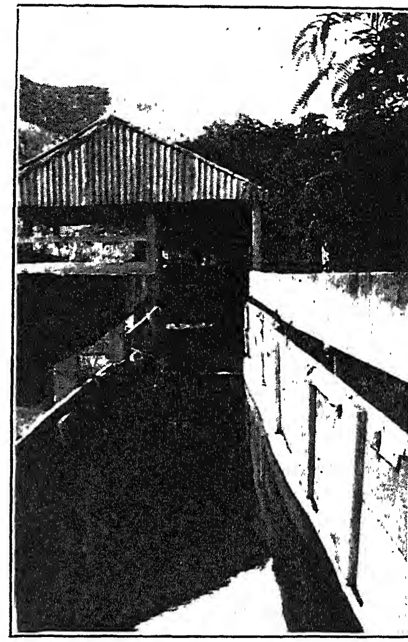


LIGHTERING PASSENGERS AT CHRISTIANSTED, ST. CROIX
A SHALLOW HARBOR, REACHED BY A NARROW WINDING CHANNEL, HANDICAPS SHIPPING IN ST. CROIX.



LOOKING DOWN ON ST. THOMAS HARBOR FROM THE HILLS BACK OF THE TOWN

St. Thomas has one of the best harbors in the Caribbean. It is deep, large and almost completely land-locked.



DIPPING TANK IN ST. CROIX

Dipping tanks are used to rid cattle of *Margaropus annulatus*, the carrier of Texas fever and a serious menace to cattle raising in the tropics.

In the opinion of many, a navy rule for this Caribbean base would be a good solution of the problem and save considerable federal outlay. Some feel that the navy did a good job for the decade or more that they were in control. They improved the roads, effectively controlled diseases and ruled with an adequate if stern justice. Moreover, under navy rule expenses can rightfully be charged to the department as well as to the Virgin Islands. It would be unnecessary to enlarge the personnel, and salary expense goes on wherever they are stationed.

The control of tropical diseases, primarily malaria, has taken a share of federal subsidy. To lessen such hazards is justified not only from a humanitarian standpoint, but also because better conditions of health will increase the efficiency of the workers and attract tourists to the islands. Nevertheless, outlay for fighting disease in the tropics is heavier than in the temperate regions and involves no insignificant expenditure.

Education and welfare costs are by no means small. One of the most serious problems with which these departments are concerned is the chaotic and disorganized condition of the home. Marital relations are so irregular, illegitimacy so common—60 per cent. of the children born—that for most of the humbler people no family life exists, and school and welfare organizations must attempt to remedy the situation as best they can. "Obeah" or the belief in evil spirits is another problem of education. Within the last few months a young woman was brought to court for "practicing Obeah." Evidence in the case was "one ordinary sized egg plant cut in two parts with two nails forming a cross driven

through the vegetable and inside a paper with the name of a victim written upside down. The plant was tied with twine." The judge fined the woman, but suspended sentence during good behavior. Although most of the natives belong to Protestant and Catholic churches, "Obeah" doctors still find believers among the superstitious Blacks. Uncle Sam has made progress in education during the eighteen years of ownership and in 1930 had reduced the illiteracy from 24.9 per cent., the figure at the end of the Danish régime, to 16.1 per cent. But much improvement is needed and money will be necessary to effect such a change.

NATIVE WOMAN WITH SLIGHT CASE OF ELEPHANTIASIS

THIS DISEASE, WHICH CAUSES ENLARGEMENT OF THE FEET AND LEGS, IS SAID TO BE SPREAD BY THE MOSQUITO, *Culex fatigans*.

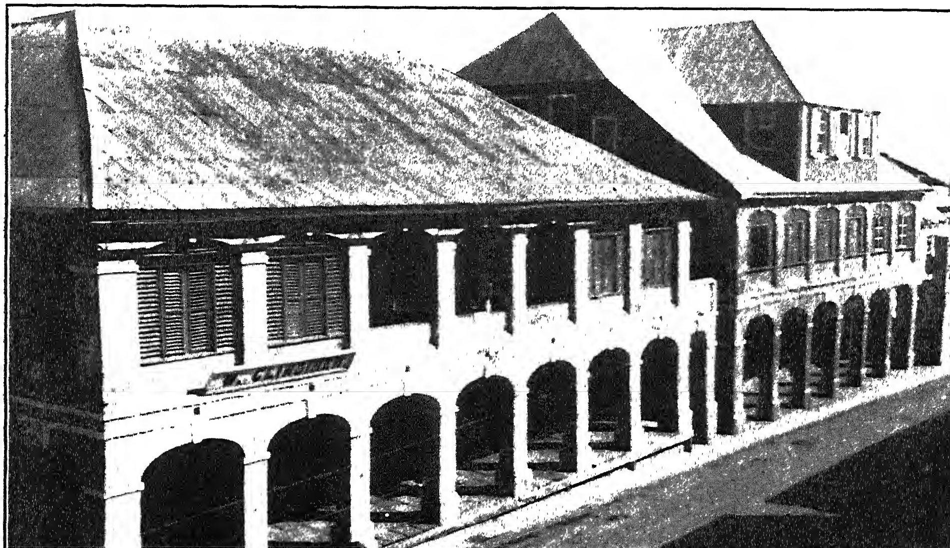
Again money is being spent on a homestead plan, whereby the surplus labor of the declining cane and shipping industries is given an opportunity to purchase small acreages and homes on long term payments. This venture may prove a good investment socially, if not economically. It should bring about the raising of more provision crops, cut down imports of several commodities which can be produced at home, and may offer a solution to many problems that are difficult to solve in a land where monoculture crowds out sustenance agriculture.

The biggest project of the New Deal in the Virgin Islands is the investment of one million dollars of PWA funds in the Virgin Islands Company. This corporation is to grow cane, distill rum and enter any other business that looks promising. The government seems willing to risk money on ventures that private capital is unwilling to back. At this writing not more than $25,000 of private funds has gone into the islands since the United States took possession. Federal money has also gone into a new hotel in St. Thomas to attract tourist trade. While there are certain handicaps to a tourist business, probably promotion money spent in that direction is less of a gamble than that devoted to other schemes. The scenery *is* most beautiful. It has already attracted one New York millionaire whose luxurious villa is built astride the mountain back-bone of St. Thomas where he can look across the island-studded sea to Puerto Rico on the west, St. Croix on the south and hundreds of smaller islands to the east. The castles of Blue Beard and Black Beard, pirates who used the islands as a rendezvous while pursuing their adventurous trade in the Caribbean, are still in good condition and should attract people interested in the romance surrounding followers of the black flag. And last, but not least, the black women and men, who with baskets on their heads coal the vessels, provide a sight not soon to be forgotten.

Other specific instances of government expenditures could be cited, but these are enough to prove that the islands serve better as a funnel for federal outlay than they do as a source of federal revenue. Moreover, the major portion of the population are not likely to object strenuously to all the money they can get. It may be remembered that 91 per cent. of the people are colored. Less than a century ago slavery existed, and economic slavery has been present within a much shorter period of time. Add to this the fact that these are tropical islands, and there will be little difficulty in understanding the "give me" philosophy of the people.

At this point the writer will "rest his case" of the Virgin Islands' economic balance sheet and study briefly their military statement of profit and loss.

War was the spur which encouraged the purchase of the Virgin Islands in 1917, and all previous attempts to buy them have been associated with their strategic value in time of conflict. A deep, spacious, protected harbor on the south coast of St. Thomas, which itself is located near the outer bend of the Antillean arc, offers possibilities for a naval base acclaimed by military experts since the United States first became interested in the Caribbean. Besides possessing one of the few good harbors in the West Indies, St. Thomas' structure, with its central ridge one thousand to fifteen hundred feet high, is especially fitted for the emplacement of fortifications commanding both shores of the harbor at the same time and making any enemy approach difficult. Moreover, while near the other islands, St. Thomas is practically in the open ocean and permits entrance and egress of a fleet with little chance of observation. Hence with these advantages it is no wonder that Admiral Porter, of Civil War fame, called St. Thomas "the keystone to the arch of the West Indies," and Major Glassford, of the Signal Corps, said that St. Thomas might be converted into a second Gibraltar.



STORE IN ST. CROIX WHERE ALEXANDER HAMILTON WORKED

BESIDES THE CHARM OF THEIR NATURAL SCENERY, THE VIRGIN ISLANDS POSSESS MANY ATTRACTIONS OF HISTORICAL INTEREST.

Our first serious attempt to purchase

the Virgin Islands came after the close of the Civil War. During that struggle the North needed a naval station in the Caribbean. Both British and French harbors had been hospitable to Confederate cruisers and blockade runners, but Federal warships found it hard to obtain coal and shelter from storms. With St. Thomas harbor as a base for coaling, supplies, repairs and shelter it seems likely that the United States could have rounded up privateers, blockade runners and contraband traders in half the time and with half the trouble.

The purchase negotiations failed at this time, and certain phenomena which have always been economic handicaps to the islands exerted no small influence on the outcome. On November 18, 1867, while a commission from the United States were visiting the Virgins in the interest of the purchase, there occurred several severe earthquake shocks which not only caused damage to life and property but also motivated a tidal wave severe enough to throw the *Monongahela*, the American Commission ship, high and dry on the shore of St. Croix. This event, coming after the terrible hurricane of October 29, gave active opponents to the purchase a chance to sneer at the attempt to buy a region of earthquakes, hurricanes and tidal waves. Moreover, several newspapers championed the opposition cause, and influenced public sentiment in the United States against the deal. In the Virgin Islands antagonism to the sale also appeared, for many ignorant natives believed that the earthquake showed the displeasure of Heaven at the contemplated change in sovereignty.

In 1902, only a few years after the war with Spain, the United States made another determined effort to buy the islands. Just as at the close of the Civil War a feeling developed that the Danish possessions provided definite military advantages, the lack of which were felt all too keenly in the recent Caribbean trouble. Authorities argued that with St. Thomas harbor in United States' hands Cervera might have been barred from the Caribbean, Puerto Rico might have fallen into American control more easily, the expense of hasty harbor defense need not have been incurred, and the loss of life and money likely would have been reduced considerably. But again the American-Danish negotiations failed, this time, however, through Danish opposition possibly brought about by German intrigue.

Finally the purchase was effected in 1917. This time champions for the United States' ownership suggested that the Germans might secure the Virgin Islands for a submarine base; and with a position so close to our shores, underwater craft might easily damage our commerce significantly

Was the purchase of the Virgin Islands a sound investment from a military standpoint? The preceding discussion affords some basis for that belief. Forgetting their economic shortcomings may be justified by recalling their advantages as an outer guardian to the Panama Canal and as an ideal site for a naval station in the Caribbean.

BIG GAME OF OUR NATIONAL PARKS

By GEORGE M. WRIGHT

CHIEF, WILDLIFE DIVISION, NATIONAL PARK SERVICE, U. S. DEPARTMENT OF THE INTERIOR

THE President of the United States designated 1934 as "National Parks Year." But to thousands of big game animals, every year is national parks year, for in the parks they find a perpetual holiday from the warfare that mankind wages against them.

In America, north of Mexico, big game means buffalo—or bison, as they should properly be called—elk, moose, caribou and deer, mountain sheep or bighorn, mountain goats which are not goats at all but really antelope, antelope which are not antelope but a rare form peculiar to the New World, and cougars, wolves and bears. One of these, the Alaskan brown bear, is the largest carnivorous animal in the modern world.

A hundred years ago, wild game still abounded from the Atlantic to the Pacific in numbers that totaled millions. In a century's time, this vast game field vanished like a continent sinking into the ocean, and there remain only small islands of game where once it stretched continuous and flourishing. The best of these island retreats, where big game animals have been spared from the destructive waves of market hunting, sport shooting, lumbering, and agriculture, are the national parks.

The story of the American bison is a tradition of our national life. By 1902 the only wild buffalo remaining in this country were in the hidden fastnesses of the Yellowstone, and they numbered only twenty. Theodore Roosevelt, who has stood forth as the great conservation President until this very day, when another of the same name threatens that distinction, asked Congress to provide for the reestablishment of a bison herd in Yellowstone Park. A few animals were brought in to augment the wild stock. From this start, careful nursing over a period of thirty years has improved the herd in size and quality, until now it is maintained at one thousand head, the very limit of the carrying capacity of the range. This is a remarkable testimonial to the untiring zeal of the buffalo keepers who have had to hold them and feed them at the Buffalo Ranch through the long winters because they could no longer migrate to the plains. Just when the Yellowstone bison seemed to have been brought safely past danger of extinction, outbreaks of the dread disease, hemorrhagic septicemia, resulted in new losses and fresh anxiety. The entire herd was inoculated with an especially prepared vaccine, and now hemorrhagic septicemia is no longer a major menace to the bison of Yellowstone.

Although the high country of Yellowstone, where bands of hundreds of bison laze away the summer, furnishes the real buffalo show of the parks, smaller show herds may be seen at Platt and Wind Cave and Colorado Monument, and there is a project now on foot to reestablish on the east side of Glacier a bison herd which will belong to the Indians of the Blackfeet Reservation, but which will summer under the watchful eyes of Indian riders.

Visitors are safe in buffalo country, for it is not this grass-eating bovine, shaggy and powerful as he appears, but man, who has furnished the element of menace in the story of the American bison. It is only the old bulls, licked out of the herd by their younger rivals and

grown cranky in the isolation of their old age, which it is sometimes just as well not to cross.

The story of the bison is far too long to be attempted here, and we may leave it at what we confidently trust may be a happy ending. But many other interesting animal faces crowd around. There are those strange parti-colored antelope of the deserts and the sagebrush mountain slopes. Though their horns have a bony core like those of sheep and cattle, they have a side prong, and the outer sheath is shed annually like the antlers of the deer tribe. The swiftness of the pronghorn antelope is a well-merited tradition. Their insatiate curiosity, which is their undoing where they are hunted, brings them no harm in the parks and frequently helps the visitor to a near view of them.

There are nearly seven hundred pronghorn on the northern game range of Yellowstone. Although this area can hardly be considered as being within their optimum range, and in spite of the fact that the hard winters crowd them down to the vicinity of Gardiner where they must compete with thousands of elk for sustenance on that depleted winter range—still they hold their own and even prosper. A recent addition to Yellowstone Park below Gardiner will benefit the pronghorn perhaps more than any other species concerned.

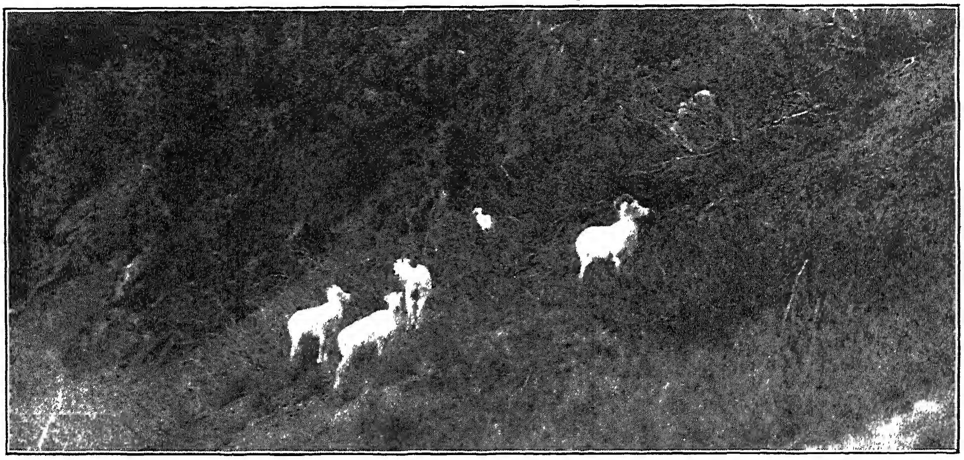
The life of these Yellowstone antelope contrasts sharply with the life of those native to the arid region of Petrified Forest National Monument in Arizona. There the President's recovery program plans to develop water catchments and is already providing a fence to exclude domestic stock and, thereby, to improve the monument's range conditions for the rightful utilizers of its range—the pronghorn which roam the hot dry wastes of Petrified Forest.

In still sharper contrast is the life of the small antelope band kept at the hot Indian Gardens far down inside the walls of the Grand Canyon. This herd, numbering some twenty-five, is being artificially maintained and protected there until such time as suitable range may be procured and made ready for them in Grand Canyon National Monument, where once again they may be safely allowed to forage for themselves in the freedom and beauty of their normal wild state.

True mountain antelopes are our mountain goats. For their welfare the National Park Service need not be concerned. When winter comes, these hardy veterans of the tumbled crags do not forsake the parks for dangerous country outside. They have no need to seek the more abundant forage of lower altitudes, for succulent herbage is always to be found where strong winds have stripped the snow from the steep slopes of the high country which they inhabit. With their short straight black horns, bearded faces and shaggy white uniforms, they stand sentinel on the rock pinnacles like policemen of the Arctic-Alpine zone.

They are plentiful in Mount Rainier, where their number, estimated at four hundred, is believed to be increasing. In Glacier they are even more abundant. No visitor to that park need leave without having seen one of their number, for the new high road across Logan Pass and the mountain chalets built in the midst of the mountain goats' home territory bring the visitor within such close range of his wary hosts that, even from his car, he may often watch them on the peaks that have been their hazardous homes for centuries.

Another dweller in the high places is the mountain sheep. Unfortunately, however, far too little is known of their ways and of the causes which have led, and seem still to be leading, to a general decrease in their numbers. Indeed, one of our chief wildlife problems to-day is

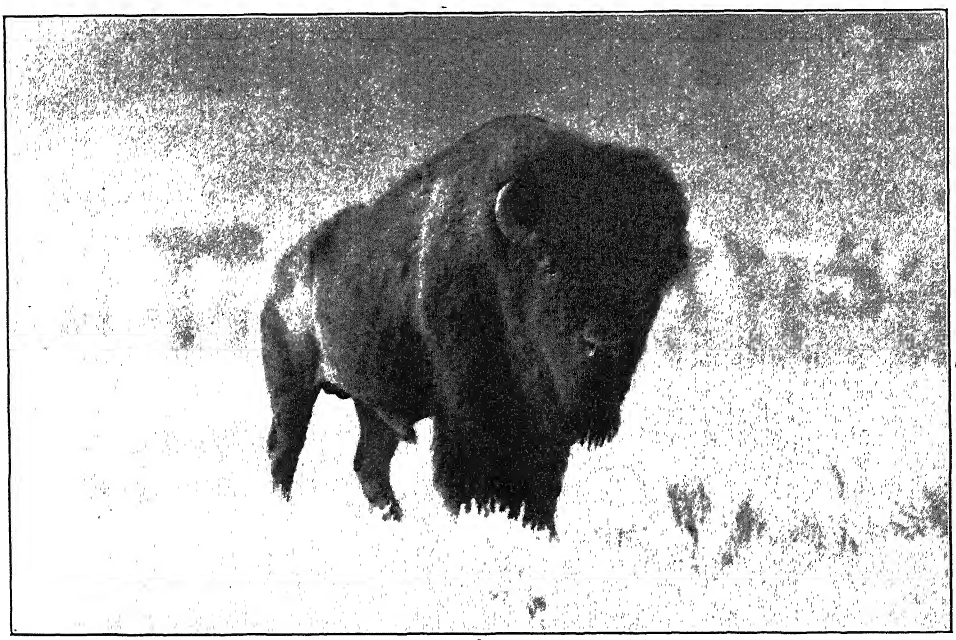


DALL SHEEP IN MOUNT McKINLEY NATIONAL PARK

Dall sheep, with their white coats and slender outward-curving horns, inhabit the rugged fastnesses of Mount McKinley.

AMERICAN BISON IN YELLOWSTONE NATIONAL PARK

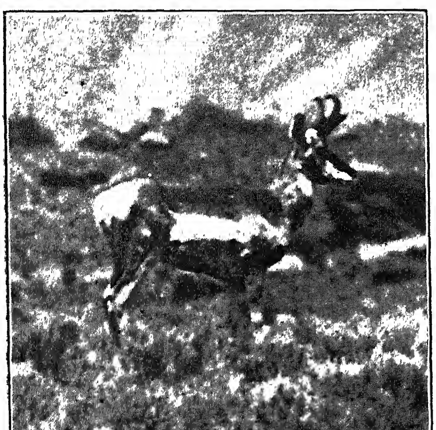
It is not this grass-eating bovine, shaggy and powerful as he appears, but man, who has furnished the element of menace in the story of the American bison.



the attempt to discover what may be done to improve their condition.

Mount McKinley is the home of the Dall sheep with the white coats and slender outward-curving horns. From a distance they look like so many white sheets spread out to dry on the fresh green grass. Recently a low ebb in the cyclical variations of abundance was reached by the Dall sheep of Mount McKinley, where their estimated numbers fell to a third of the 1929 level. Though such cycles of abundance are in themselves a natural phenomenon caused in part by bad weather and the depredations of wolves and coyotes, yet man has added so many more hazards that the time may come when recovery is impossible. Increased protection for the sheep outside the park and a limited control of their natural enemies within the park are the only present means of stemming this dangerous ebb, and latest reports of what is believed to be a slight increase may indicate that the tide is already turning.

The tan-colored Rocky Mountain bighorn are found in Glacier, Yellowstone, Rocky Mountain and Grand Teton. In these parks, too, the sheep seem to be slowly declining in number, unable to cope with the many factors hostile to their welfare. Some of these hostile factors which we can already diagnose are their apparently low resistance to disease, range competition with elk (as in Yellowstone) or with domestic sheep (as in Rocky Mountain), coyote depredations and even, it is suspected, poaching. Careful study and zealous care is necessary if we are to save the Rocky Mountain bighorn from all these hazards.



AMERICAN PRONGHORN

THEIR INSATIATE CURIOSITY BRINGS THEM NO HARM IN THE PARKS.

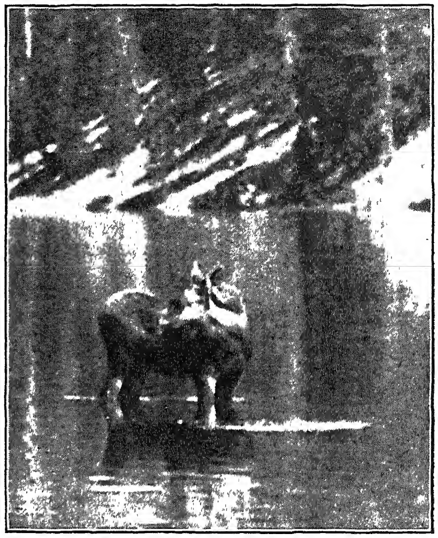
Very little is known concerning the sheep of Grand Canyon. These faded-out desert bighorns, with their very massive, tightly curled horns, live in the canyon below the rim, and, in their practically impenetrable habitat, they are seldom seen. It may be assumed, however, that the recent removal of over a thousand feral burros may react favorably upon their food supply and consequently upon them.

The various members of the deer family are the bright spirits of the park forests. The tall dark stranger with the broad, palmed antlers, who stalks through the willow thickets of Grand Teton and Yellowstone in white-stockinged feet, is that giant deer, the Shiras moose. Since they are hardy and do not migrate in herds to the lowlands in winter, they find ideal protection in the high country of the parks. Nearly every day they may be seen along the main road between Norris and Mammoth Hot Springs, in Yellowstone's Willow Park. One day last summer a moose cow and her calf stood feeding in the Yellowstone River, their demeanor as placid as the dark green water that smoothly swirled around their legs, while from the banks there arose a din of excited exclamations and camera shutters.

Glacier, too, has its American moose, some one hundred and fifty of them—perhaps more, for they have lately been seen there in valleys hitherto unfrequented by them.

A new member of the resident fauna of Mount McKinley is the Alaska moose, the largest and blackest of the moose tribe. It is only since 1926 that they have been more than casual summer visitors to the park, but the recent inclusion of lands of lower altitude within park boundaries, together with the cumulative effects of protection, and possibly persecution outside the park, may have led them to adopt this high refuge where living conditions are otherwise less favorable.

Caribou are the deer of the north, weird animals seen drifting like wraiths across the tundra twilight. The grotesque, uneven antlers are worn by the females as well as by the bulls, and in this they are anomalous in the deer world. A hard battle is being waged to prevent the fine large barren-ground caribou of Mount McKinley Park from crossing with the dwarfish but aggressive reindeer imported from the Old World.



SHIRAS MOOSE

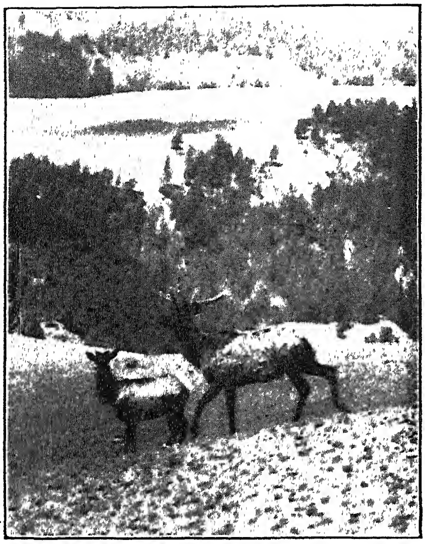
A CALF STOOD IN THE YELLOWSTONE RIVER, ITS DEMEANOR AS PLACID AS THE DARK GREEN WATER THAT SWIRLED AROUND ITS LEGS.

Because it has had so much publicity, the mention of elk usually conjures a picture of famed Jackson's Hole south of Yellowstone Park. But there is also a large herd of more than ten thousand elk that mingles with the southern herd in summer but goes down on the north side of the park to winter. Then there are the smaller herds of Glacier and Rocky Mountain, reintroduced from Yellowstone stock, as were many other herds of elk now found on the national forests and elsewhere outside the parks system.

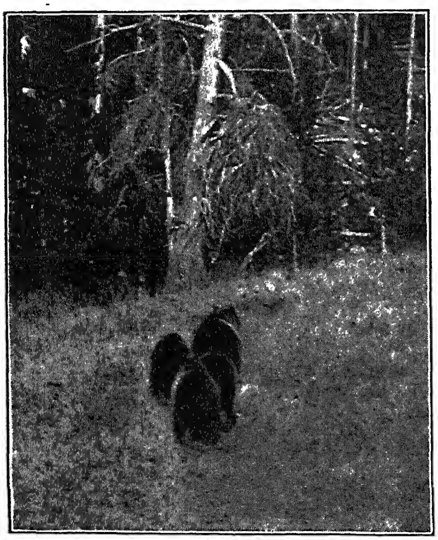
Summer is lavish in its gifts to the elk. They are well protected in the interior of the parks and the grasses are lush. There they drop their calves, which are soon running gaily beside their mothers. When chilly nights change summer to gaudy autumn, the fat sleek bulls bugle from every hillside and make ardent love. Then one morning the ground is white, and winter with its weakening cold and hunger steals down to deal death among them. Hunters wait below, but this end is a merciful one, for domestic cattle have stripped their winter lands of forage and there is not room enough for all. The government maintains winter feed grounds, but elk, like human beings, are not improved by being pauperized. The only way to save the elk herds is to secure adequate winter range for them.

Deer, including the sturdy Rocky Mountain mule deer and the graceful white-tailed deer with its white signal plume, are well represented in the parks. Glacier is notable for having large numbers of both types, and Yosemite is famed as the Eden-like garden where deer and men live side by side as neighbors and friends. In fact, the ability of deer to adapt themselves to joint residence with man—together with the special protection they have had in the past through control and often even elimination of their natural enemies—

has in some instances created a problem of adjustment of numbers to range carrying capacity. The National Park Service and the United States Forest Service favor the policy of managing the Kaibab deer herd to permit its gradual increase as the range is brought back to normal productivity; and a careful and constant study is made of both deer numbers and range conditions there. On the South Rim of the Grand Canyon, water holes for deer are being constructed, and about sixty square miles of range have been fenced to exclude stock. Further game range studies by the use of fenced and unfenced quadrates and checkplots have been proposed for Yosemite, Sequoia, Zion and Mesa Verde, and such quadrates have already been constructed in Rocky Mountain and Yellowstone.



AMERICAN WAPITI
ELK ARE WELL PROTECTED IN THE PARKS.



GRIZZLY BEAR
NO ONE WHO HAS EVER SEEN THIS MAGNIFICENT BEAST AT OLD FAITHFUL OR CANYON CAN ABIDE THE THOUGHT THAT HE SHOULD EVER DISAPPEAR FROM THE FACE OF THE EARTH.

Cougars are seldom seen, but the knowledge that they are present adds interest to the mountain trip. Besides, they are a valuable part of the whole of nature's plan. It is the presence of its natural enemy, the cougar, which has made the deer that swift alert animal which we so much admire. In the parks all native species receive protection, so that nature's balance may to the greatest possible extent be preserved. Even the wolf is given consideration, but unfortunately it has already disappeared from all the national parks of the United States proper. The handsome timber wolves of Mount McKinley, which attain a length of seven feet and more, need special protection, for the wolf, like the cougar, has hardly a friend and is headed for extinction.

Lastly come the bears, the clowns of the animal world, the bears of comic reputation. Black bears encourage intimacies, but the wise visitor will heed the advice of park officials and remember that it is always better to meet the friendly advances of the cheerful black bear a good deal less than half way.

The grizzly bear is an animal of another temperament. Lord of all the lands he roams and the most powerful of the big animals is King Grizzly, although to-day his park domain is limited to Mount McKinley, Glacier and Yellow-

stone. No one who has ever seen this magnificent beast visiting the feed platforms at Old Faithful or Canyon can abide the thought that he should ever disappear from the face of the earth. Fortunately, the grizzly seems to be increasing in the parks, even though his numbers are declining elsewhere.

This is the roster of big game animals in the parks. There are, of course, besides these large animals many others of less size but equal interest, including the coyote, beaver, otter, marten, wolverine, badger and a host of others. These, too, find refuge in the national parks, for the money value of their fur, or their interference with man's agricultural pursuits, has made many of them as much in need of protection as the larger targets, the big game.

Conservation-minded citizens have come to depend on the National Park Service to protect the prized remnants of our almost-vanished large mammals. Old-time rangers tell many an interesting story of long hard winters when they fought side by side with the buffalo and elk against the stalking deaths of poaching, starvation and disease. It is apparent that those darkest hours for conservation are past, but there is still the greatest necessity for unrelenting watchfulness and care.

To the vacationist and the seeker after adventure, as well as to the conservationist, the parks have much to offer. They are the last flourishing remnants of a lost game continent, where one who is weary of cities may still be refreshed by a taste of wilderness and thrilled by a glimpse of the rightful masters of wilderness—the big game.

THE DEVELOPMENT OF DYNAMIC EXHIBITS IN BIOLOGY

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Now that A Century of Progress International Exposition has become history it would seem that a fitting time has arrived at which to consider some of the problems encountered during the development of some of its exhibits, to weigh the shortcomings as well as the benefits which we may reasonably expect to accrue from these exhibits. The biological exhibits of the Hall of Science will form the major theme of this discussion, although it will prove necessary to mention exhibits displayed elsewhere in that building, because of their biological nature.

A Century of Progress was conceived in a time of prosperity, but was constructed and opened to the public in a time of severe depression. Consequent budget reductions should be borne in mind during consideration of the comments which follow. When science was selected as the theme for the exposition, the National Research Council was asked to cooperate in the preparation of a plan covering the displays that were to be made in science. A special committee was appointed. This committee in turn selected subcommittees to deal with the appropriate fields of science.

In biology, subcommittees prepared excellent reports in anatomy, bacteriology, biology, botany, entomology and physiology. The reports of these committees were available when the permanent staff was brought in by the exposition management to create the actual exhibits. The scope of these reports was staggering. It has been conservatively estimated that ten million dollars would not have covered the expense that would have been involved had the exhibits which were suggested been carried through to completion. The exposition had received exactly what it requested, namely, a description of the exhibits necessary to present a century's progress in science, regardless of cost.

Instructions from the management to the scientific staff were in the main simple and to the point. Exhibits acquired were to tell a story, were to fit into the requirements of space and budget, were to follow the spirit of the National Research Council reports, and, finally, wherever possible, were to be dynamic.

This brief review leads then to the major problems which faced the biologist. What exhibits should he leave out? What was a dynamic exhibit? How should he build a dynamic exhibit? The first question was answered by the exposition for all who visited the Hall of Science. It will be commented upon from time to time throughout this article. The second question must now be answered, while the third question will be answered a little later.

We generally think of turning wheels and bubbling liquids when the words "dynamic exhibits" are mentioned. The Hall of Science, in fact the entire exposition, was full of them. They were the ideals toward which every exhibitor strove, with the earnest belief that they represented the height of exhibit excellence. The value of this type of exhibit for biology was recognized by the National Research Council committees and by the exposition staff. Motion is still the most powerful magnet in attracting the attention of man. Motion, in a fundamentally interesting subject, will attract and hold attention. But mechanical motion in an exhibit is hard to obtain

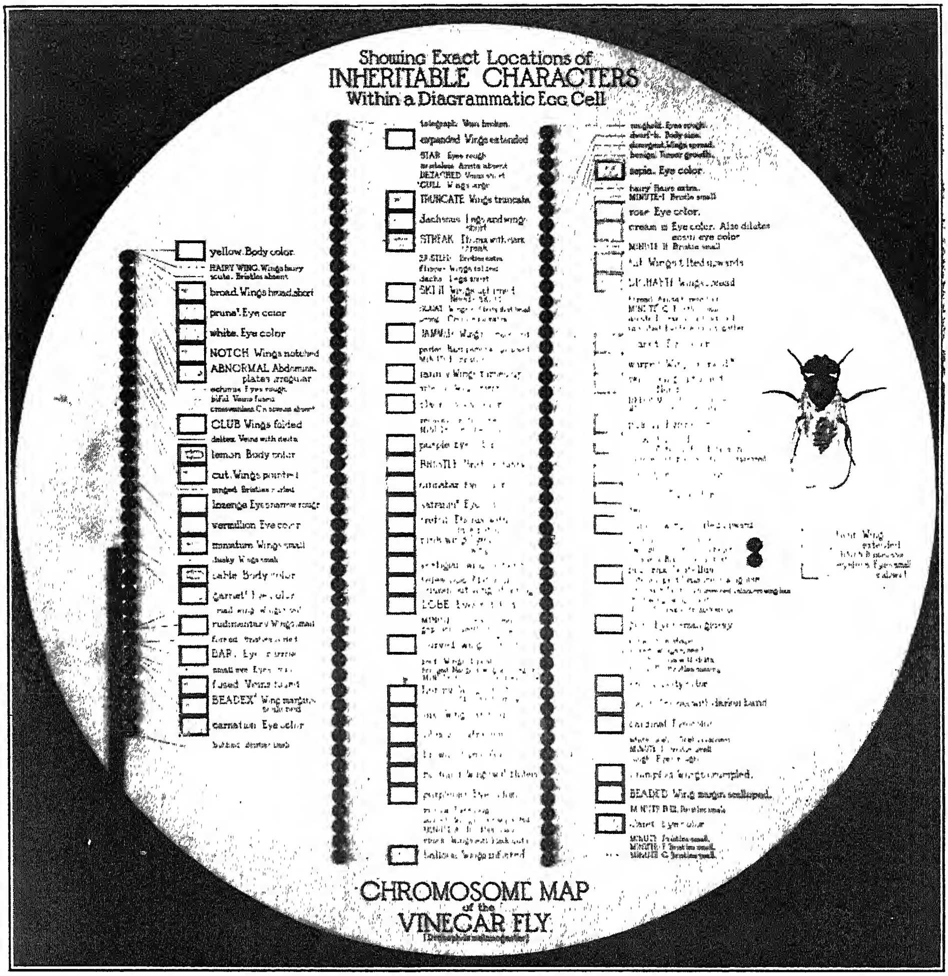

FIG. 1. CHROMOSOME MAP OF DROSOPHILA

THE YARDSTICK AT THE LEFT INDICATES THE SIZE OF THE PANEL. THE SMALL PICTURES WERE COLORED ON THE BACK, SO THAT WHEN ILLUMINATED THE COLORS WOULD APPEAR. EYE COLORS, BODY FACTORS AND WING FACTORS WERE ILLUMINATED IN THE ORDER MENTIONED. A NUMBER OF THE CHARACTERS WERE PICTURED FROM THE LIVING FLIES.

if the exhibit is to tell a story and, furthermore, it is very expensive. Motion, plus light, plus pictures, plus sound in the form of a speaking record, plus grotesqueness in construction, plus also a place to sit down, proved capable of attracting and holding many people for considerable time in the anatomical-physiological exhibit of food chemistry adjoining the biological section. But this one display cost many thousands of dollars and was out of order a considerable proportion of the time.

We must then add light and sound to the possible characters of a dynamic exhibit, and perhaps we should separate light into flashing light, changing light (Fig. 1), colored light and ultra-violet light. Sound may be divided into musical sound, recorded speaking voices and noise. The motion picture, the changing lantern slide and the living human dem-

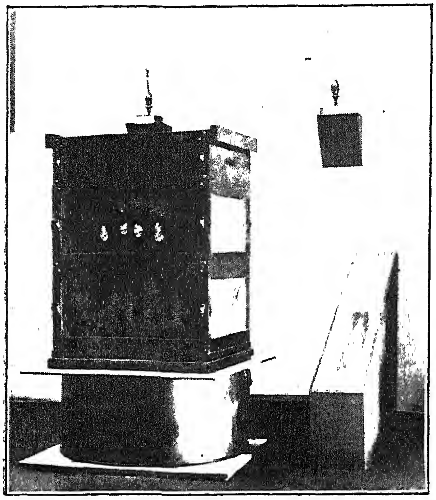

FIG. 2. LIVING COLONY OF BEES IN ROTATING HIVE

THIS HIVE TURNED CONSTANTLY THROUGHOUT THE FIVE MONTHS OF THE 1933 EXPOSITION. THE BEES WERE FREE TO ENTER AND LEAVE BY THE CHUTE CONNECTED WITH A HOLE IN THE WALL OF THE BUILDING.

onstrator offered other possibilities for dynamic exhibits.

But the biologist had available still another type of dynamic exhibit which was not available to others. This type of exhibit involved the use of living plants and animals. Man's interest in these creatures is fundamental, certainly next to his interest in his own species. He first lived with and fed upon and fought other living things for survival itself. Then he learned to domesticate animals, working some and keeping others for pets. An exhibit of animals alone or of animals performing is usually well attended. Witness our flea circuses, our five-ring circuses, our rodeos, our races, our stock shows and our zoological gardens!

Museums of Natural History have only recently begun to capitalize upon displays of living animals. They seemed entirely appropriate as features of our section of the Hall of Science. Living guinea pigs displayed in lighted cages with sloping mirror-lined tops provided demonstrations of the method of inheritance of coat factors and eye colors in the genetics exhibit and always held the children. A living colony of bees in a revolving glass-windowed hive (Fig. 2) proved entirely practicable, required no attention and demonstrated social insects in a manner that could not have been excelled. Living tobacco plants, descended from x-rayed pollen and seeds, were kept in bloom throughout 1933 and demonstrated modern work in genetics. Living plants were used in botany and living rats in the vitamin display. But our finest and most dramatic dynamic ex-

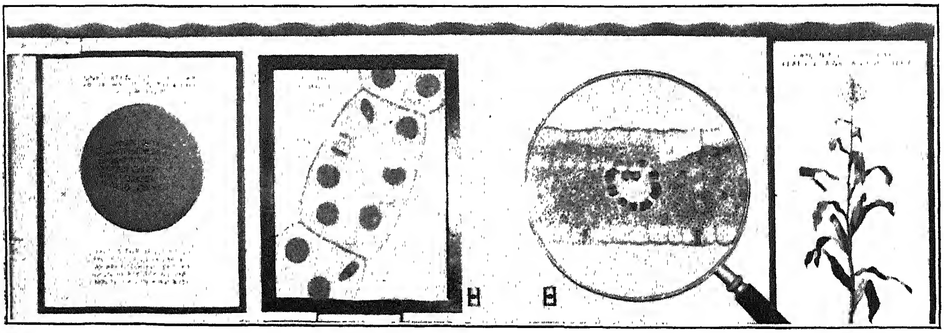

FIG. 3. LEAF ACTIVITIES

FROM RIGHT TO LEFT, THE SECOND EXHIBIT ILLUSTRATED FREE DIFFUSION OF GASES INTO AND OUT OF THE LEAF, AND THE GASES WERE REPRESENTED BY DIFFERENTLY COLORED PITH BALLS, DRIVEN BY COMPRESSED AIR. THE THIRD EXHIBIT MADE USE OF MOVING STREAMS OF CIRCULAR LIGHT SPOTS TO ILLUSTRATE THE MOVEMENT OF VARIOUS SUBSTANCES INTO AND OUT OF THE LEAF IN THE DAYTIME AND AT NIGHT TIME.

hibit was a battery of projections of living micro-organisms displayed as the Microvivarium. This exhibit was undoubtedly the most popular and instructive unit in the Hall of Science and is to be maintained in one of our museums. No wheels, no fire, no dramatics save a superb presentation of living organisms with occasional oral explanations!

Motion pictures may be considered the last resort of the hard-pressed exhibitor. They have already taken their place in museums, automobile shows and other trade shows, store windows and similar places where a story must be told with action, detail and clarity. Many films operated continuously in the Hall of Science, yet few were to be found in biology. Like all good things, this method of demonstration palls upon a foot-weary public, which refuses to stand for a minute or two minutes to watch films when they are accustomed to see them while sitting down. Furthermore, the production of original and effective films is an expensive matter, and a stalled projector is a thing of danger, even with safety film. Time and again when a method of mechanization or dramatization seemed impossible of solution the time-worn suggestion was heard, "make a movie of it." One excellent film was projected continuously, showing yeast cells apparently growing and budding in a fluid medium. The image was thrown into a pan of water and reflected into the view of the visitor. This film and method of display was unique in the entire exposition.

One can not pass by an analysis of dynamic exhibits without mentioning one characteristic possessed by certain exhibits in biology which placed them in the dynamic category, though they had no motion. This quality is human interest.

In general it might be said that human interest is possessed by any subject which concerns the observer intimately

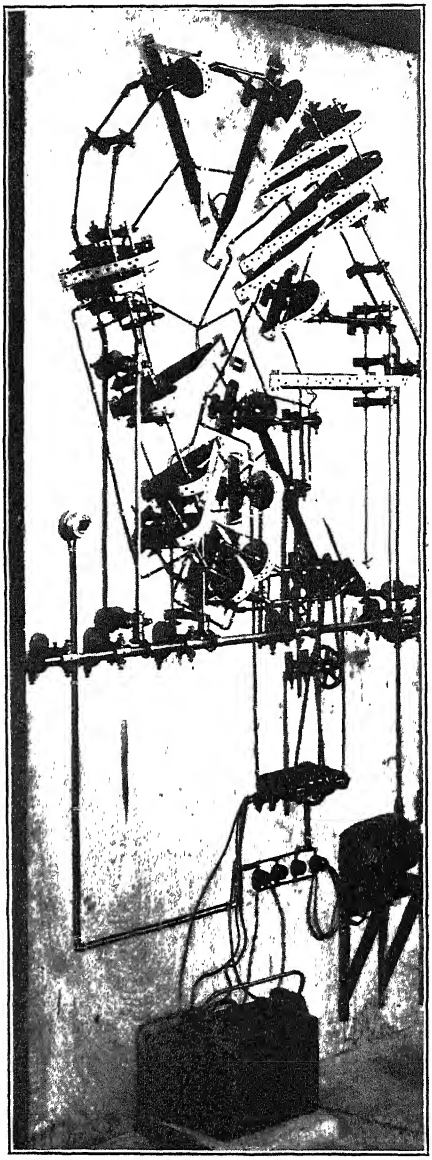

FIG. 4. REAR OF LEAF CELL MECHANISM

SMALL LIGHTS IMBEDDED IN THE PANEL SHOWED THROUGH THE HOLES IN THESE BELTS, TO APPEAR IN DIFFERENT COLORS ON THE FACE OF THE EXHIBIT SHOWING CELL ACTIVITIES OF THE LEAF. NOTICE THE FLEXIBLE SHAFT DRIVEN AT BOTH ENDS BY THE MOTOR. MECHANISMS SUCH AS THIS HAD TO BE PLANNED AND MODIFIED WHILE THEY WERE BEING BUILT.

or which has come forcibly into his experience. It may include revelations concerning his own growth and development or anatomy, if these subjects are presented in a way that is not gruesome. A series of human embryos ranging from five weeks up to nine months of age proved the best remembered and most sought after display in the Hall of Science. Only the Microvivarium drew larger crowds, while the Transparent Man of Medicine should certainly rank third. The interesting feature concerning the crowds which visited the human embryos was the lack of official advertising and advance publicity accorded this display. The Transparent Man was featured from coast to coast in pre-fair advertising. The Microvivarium received its published publicity after the fair was well under way. The human embryos were advertised by word of mouth among fair visitors. A really good exhibit requires no blare of trumpets. That much A Century of Progress taught unbelieving showmen, in several instances.

Another feature in biology possessing no dynamic characteristic save human interest was the combination display of Piccard's second gondola and Beebe and Barton's bathysphere. The public had read of these unique pieces of apparatus and rightly expected to find them in the Hall of Science. The fact that they were brought in by biology, as demonstrations of new methods evolved by man to enable him to explore regions in which his anatomy and physiology would not permit him to survive without them, did not keep them from being excellent exhibits for either physics or chemistry. They had human interest and were thus dynamic and of interest to visitors.

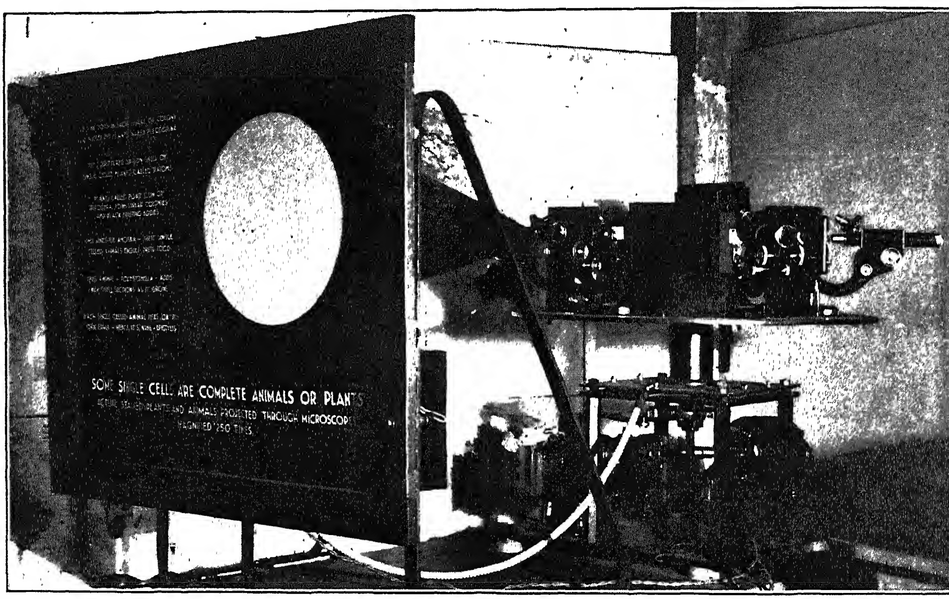

FIG. 5. ROTATING MICROSCOPE MECHANISM

THIS WAS THE FIRST WORKING EXHIBIT TURNED OUT BY OUR SHOP. THE ILLUMINATED LABELS LIGHTED UP AS EACH MICROSCOPE CAME INTO PLACE. STANDARD MICROSCOPES WERE USED IN THE EXHIBIT.

The crowning dynamic exhibit should have been one where an attendant was present or perhaps a technician was at work. It seemed that preconceptions along this line were at fault. These ex-

hibits did not draw as our scientific staff expected that they would. Perhaps the explanation lay in the constant sales talks which the visitors encountered in other places in the exposition where attendants were placed. The visitors seemed to build up an unpleasant association which held where attendants were to be found inside booths or behind rails. If the attendant was outside the exhibit or the rail surrounding the display they did not shy from him. He was besieged with questions.

Many men of science visiting the Hall of Science could rightly wonder at the omission of certain recent discoveries, of certain vital displays of processes and of fundamentals that they rightly expected to find in biology or in any of the other sciences. They could not all be included. Many did not lend themselves to display. Many were too costly or too involved to include, and many were earnestly planned but could not be obtained or fitted into the limited space available. When one remembers that the original recommendations of the biology committees alone were estimated to require

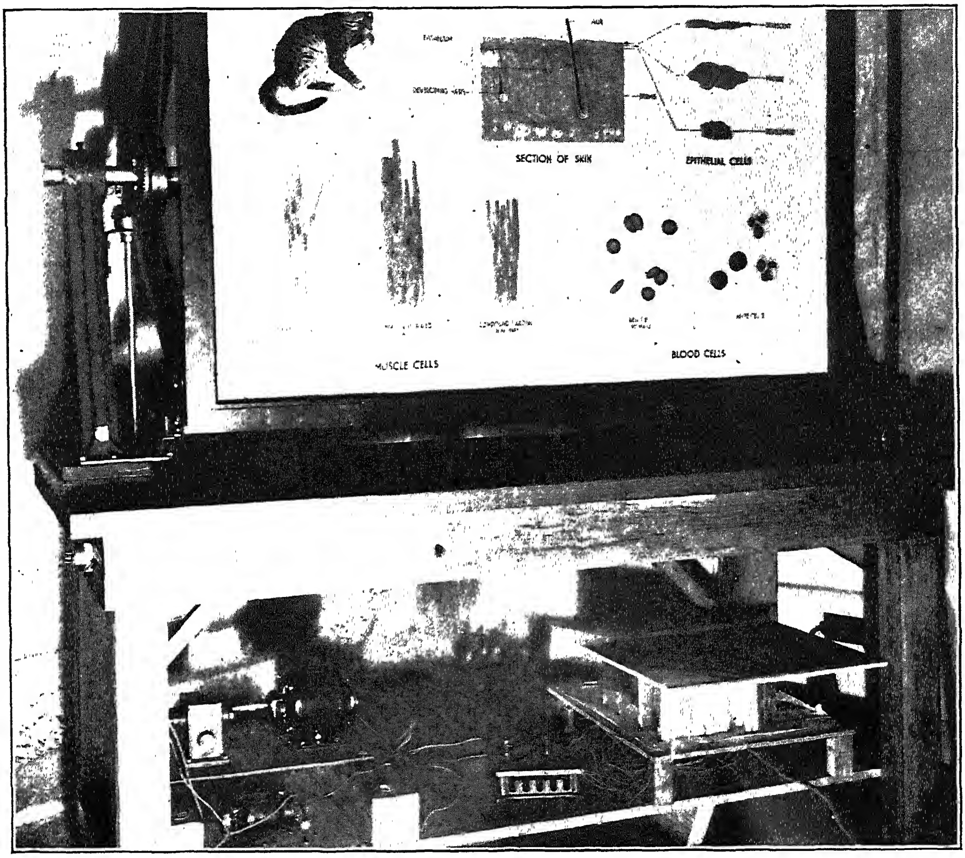

FIG. 6. ANIMAL CELL TRANSPARENCY MECHANISM

THE THREE TRANSPARENCIES MOUNTED IN THIS REVOLVING FRAME WERE PAINTED IN TRANSPARENT OILS ON WHITE VELLUM. ALL DEALT WITH THE HISTOLOGY OF THE CAT, AS AN EXAMPLE OF ONE OF THE MULTICELLULAR ANIMALS. THE DISPLAY WAS LIGHTED FROM THE CENTRAL AXIS AND TURNED AT INTERVALS, AUTOMATICALLY. THE MOTOR AND TIMING MECHANISM ARE SHOWN AT THE LEFT, BELOW.

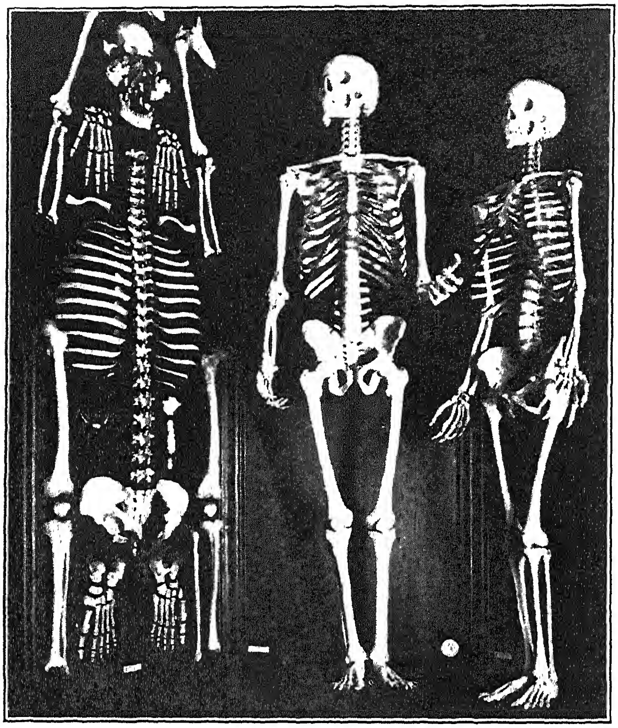

FIG. 7. THE HUMAN SKELETON. THE CENTRAL SKELETON IS MECHANIZED

THIS CENTRAL SKELETON TURNED ITS HEAD FROM SIDE TO SIDE, RAISED AND LOWERED THE RIGHT ARM, ROTATED THE LEFT HAND AND SHOWED BREATHING MOVEMENTS.

over fifty thousand square feet of exhibit space, and when one realizes that biology alone had only approximately twelve thousand square feet of net space, expanded from an original assignment of six thousand, it is more easy to understand why many valuable exhibits could not be included.

The writer is not yet positive that he could construct a giant cell in whose nucleus mitosis would take place mechanically, with all cell parts faithfully represented. Nor is he quite certain that it would be possible to construct a tree of life, made up of winding corridors of displays of all the proper creatures to be found along this theoretical tree. He might have difficulty pleasing both those requiring a normal tree and those demanding a diphyletic tree, though for a time he hoped he would be successful in constructing a vertical tree twenty-five feet in height, in three dimensions, on which such models could be placed! Nor is he certain he could build a corn leaf sufficiently enlarged to permit the visitors to enter the stomata and clamber through the intercellular spaces amid colored steam or smoke representing the proper gases involved in photosynthesis, while slipping up and down over translucent cells with chloroplastids at work! The exhibits shown as Figs. 3 and 4 were a stride in that direction, but even they proved difficult to keep in operation. The insect larva, whose mouth the visitor was to enter, to pass through the digestive tract with normal life processes occurring alongside him, and to emerge from the posterior end of the young insect, will have to await a future, greater exposition, not only planned but executed in times of prosperity.

Exhibits showing actual animal experimentation in physiology will never be seen outside of classes in physiology in college or medical school, while actual demonstrations of human anatomy by dissection must be sought in the same manner. The latter suggestion was materialized in the medical section, along somewhat different lines, however, in the presentation of mounted slices of human bodies, excellently stained and preserved. The majority of the visitors thought them models and marveled at the uniqueness of the "frames" that were used around them.

Counts were taken at various exhibits of different types, at different times of

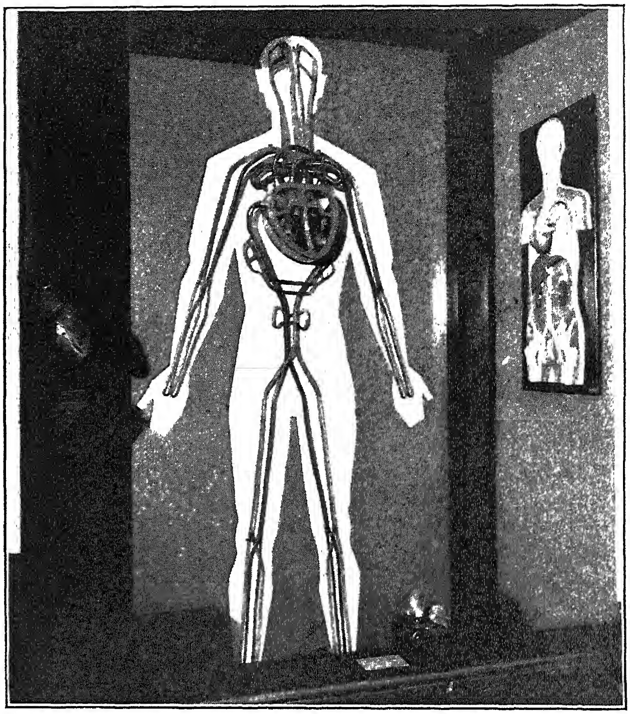

FIG. 8. THE CIRCULATION OF THE BLOOD
THIS MODEL, TEN FEET IN TOTAL HEIGHT, ILLUSTRATED A SIMPLIFIED CIRCULATION OF THE BLOOD AND SHOWED VALVE ACTION IN THE HEART WITH EACH BEAT. BEATING WAS PRODUCED BY CHANGES IN THE RUBBER BACKWALL OF THE HEART. NOTICE THE LIGHTS IN THE SIDES OF THE HEART.

the day or week, to determine popular exhibits in biology and to permit a study of the relative value of these different types. Dynamic exhibits led all others by a wide margin, particularly where the visitor could do something to make the exhibit move. This statement applies to all exhibits in biology, exclusive of the human embryos and the Microvivarium. Our studies left no question as to the value of the dynamic display. Charts and models, dioramas and other displays, no matter how exquisitely or appealingly constructed or how faithfully represented, could not hold the average visitor unless some dynamic quality were present. When the entire display was static the problem was a different one. When some displays were static but others were dynamic, the showman had to provide for crowds around the dynamic ones.

The question concerning methods of constructing dynamic displays must now be considered. Few of our units were constructed from blueprints. Most of them began as rough pencil sketches by the head of the section, which were then discussed with the chief of the experimental shop. A few special prints or drawings were made to aid in the determination of costs, for all such models had to be approved financially before work was undertaken. Each unit made in our shop had to be followed closely as the work of construction progressed, with changes being made as the necessity arose. Our first unit to be constructed was the rotating microscope exhibit, which permitted the projection of six different microscope slides at thirty-second intervals of display with five seconds between slides. By mounting six microscopes on a rotating plate (Fig. 5) this was accomplished with no change in focus, once all slides had been properly set. The labels changed with the slides.

The rotating transparencies (Fig. 6) of the cell unit were a serious problem because of the weight of the transparencies and the size of the sheets of glass involved. A unique timing device controlled the movement of the transparencies and the illumination.

The mechanized skeleton (Fig. 7) of the anatomy unit proved irresistible to visitors through its arm and head movements. This display required careful bone-drilling and assembly by a master craftsman. Most of the visitors failed to

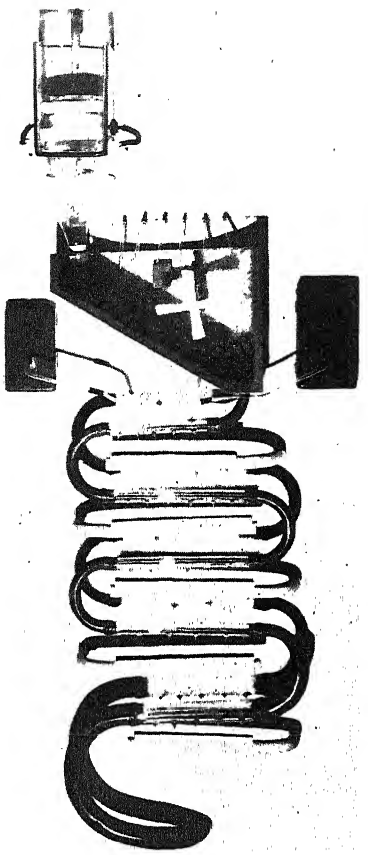

FIG. 9. HUMAN DIGESTIVE MECHANISM
THIS DIAGRAMMATIC MODEL, WHEN COMPLETED, WAS CROSS-LABELLED WITH A PLASTER MODEL OF THE HUMAN DIGESTIVE SYSTEM. RUNNING WATER REPRESENTED FOOD ENTERING THE MOUTH AT THE TOP, WHILE VARIOUSLY COLORED DYES REPRESENTING DIFFERENT DIGESTIVE JUICES ENTERED BY THE SMALL GLASS TUBES.

observe the slight breathing movements of the chest.

Despite the apparent simplicity of the mechanized digestive system (Figs. 9 and 10), an attempt to simplify a very complex process, this unit was rebuilt twice before it could be operated effectively as a dynamic exhibit. Water and dyes had to be adjusted or regulated daily. This and the other displays, such as the human circulatory system (Fig. 8), proved that dynamic exhibits will be watched and studied by the public in a way that a static model can never equal.

Thousands of visitors watched the mechanized stories of the migrations of the Alaskan salmon and the freshwater eel. In their usual manner, few read the labels, but every visitor understood the migrations as he watched the young fish and the mature fish move in opposite directions, to and from the spawning grounds.

Panels and models proved effective accessories to dynamic exhibits as shown by the pollination of a flower (Fig. 11) and the movement of materials in a stem (Fig. 12), two units in botany. The first of these dynamic units used mechanical motion and light, while the latter was made dynamic only by the movements of colored water. Botany lends itself well to dramatization with dynamic exhibits, and much should be done along these lines in the future. The exhibits on leaf activities (Figs. 3 and 4) have already been mentioned.

Paintings and groupings of animals and plants of various habitats were enlivened by a great colored world map (Fig. 13) whose changing lights illuminated various world areas. This type of exhibit can be used in our museums to clarify the habitat groups and offset the monotony of rows of cases of mounted animals. Trends in this direction can already be seen.

Living bees have been kept in museums, but the hives have never been set in motion. Our rotating hive (Fig. 2) gave the visitors a view of all sides and in no way disturbed the bees, which continued to enter and leave the building and the hive in normal manner. They stored much honey during the exposition.

The growing twig (Fig. 14) was probably our most elaborate venture in the field of dynamic, mechanized exhibits. This device was developed to demonstrate the method of secondary growth exhibited by a three-year-old twig of the basswood or linden, *Tilia* (Fig. 14, upper and lower left).

The writer had felt the need of such a model from the first time he tried to demonstrate to a botany class just how secondary growth occurs in certain trees or twigs. Before attempting to construct the working model, he developed a smaller model, representing a small segment of the twig, using cardboard, metal clips, cheesecloth and rubber bands. The full scale model was then begun. Only three of the thirty-two sections eventually used were constructed, until their action had been thoroughly tried out. A hand crank was temporarily used for motive power.

Details of construction and operation are given as an indication of some of the problems to be encountered if biological phenomena are to be represented by working models of large size. The reader has been spared construction and operation details for other exhibits of the dynamic type.

A great angle-iron ring, some seven feet in diameter, was mounted vertically on a very rigid and heavy group of uprights (Fig. 14, right). A five-horsepower motor with special gear reducer, mounted securely on the base of the upright frame of the model, drove, by means of a heavy noiseless chain, a bronze gear, some twelve inches in diameter, mounted exactly in the center of the great ring previously mentioned. The outer edge of one face of this bronze gear bore numerous fine teeth which engaged thirty-two small pinions held rigidly against the gear.

Each of these pinions was mounted on a spindle, with all spindles radiating from the center to the outer edge of the ring frame. Each spindle was cut with threads of two different pitches. The majority of the thread was considerably finer than that placed on the outer several inches of each spindle. Specially cut and shaped nuts with bronze bushings rode these threads, guided by steel strips that also radiated from the center of the frame to the outer edge of the ring. A thin plate of galvanized iron was firmly screwed to each outer sliding nut, and these plates were mounted at two different levels, so that every alternate plate could slide over the plate adjoining it.

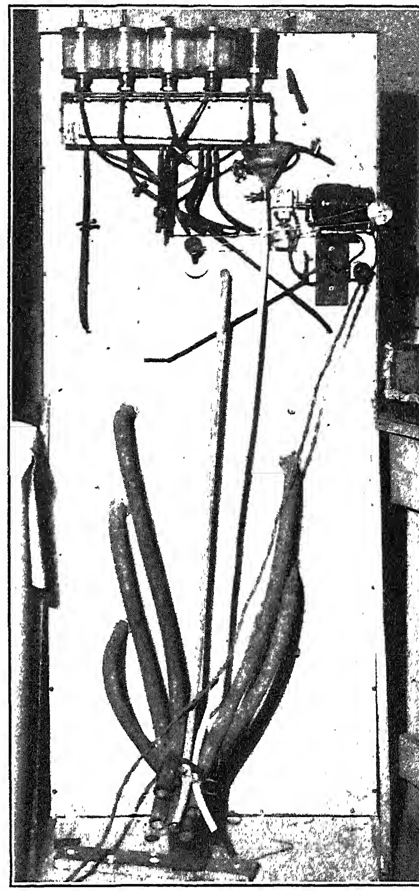

FIG. 10. REAR VIEW HUMAN DIGESTIVE MECHANISM

THE MOST PROMINENT FEATURE OF THIS VIEW OF THE EXHIBIT IS THE GROUP OF TUBES COLLECTING THE FOOD AND WATER ABSORBED BY THE SMALL AND LARGE INTESTINE. THE MOTOR DROVE THE MIXER IN THE STOMACH AND IMPARTED THE CHEWING MOTION TO THE PLATES REPRESENTING THE TEETH. THE OILERS SHOWN AT THE TOP WERE THE ORIGINAL FEEDERS FOR THE VARIOUS DIGESTIVE DYES.

These plates were made large enough so

that they could be painted with cell detail and could show background on their outer borders, then epidermis, cortex and pericycle. Other plates were then cut in the shape of elongated flat-irons and were mounted at alternate levels on the same nuts that bore the large plates first described. They were, however, elevated about a half-inch from the surface of these background plates. These smaller blocked up at each end, with a duplicate covering strip on top of the blocks. A fine steel rod connected the two end blocks of each arc and a fine brass tube was fitted on each of these rods to serve as a roller which turned freely between the upper and lower curving strips just mentioned.

When the inner nuts were drawn as far toward the center of the model as the

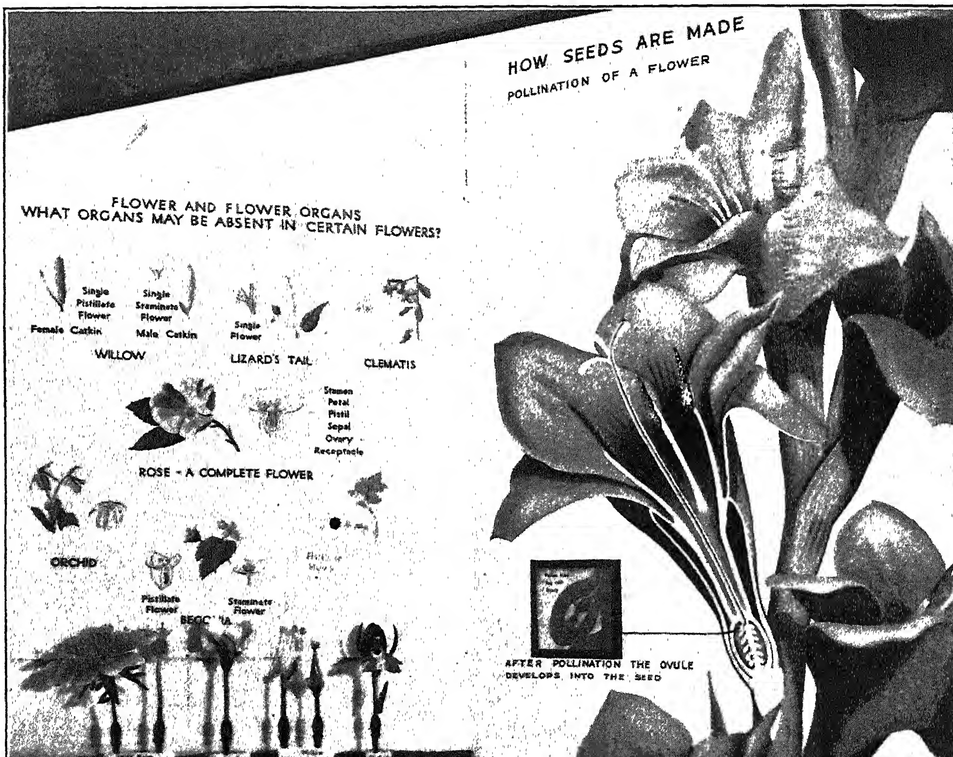

FIG. 11. POLLINATION OF A FLOWER

THE "BALL BEARING" POLLEN GRAIN MOVED DOWN ALONG THE DOTTED LINE FROM THE UPPER FLOWER TO THE LOWER, THEN SPROUTED, WITH A LENGTHENING LINE OF LIGHT UNTIL THE OVULE WAS REACHED. THE TRANSPARENCY ON THE LEFT THEN LIGHTED AND TURNED THROUGH FOUR STAGES TO SHOW SEED FORMATION. MEANWHILE THE POLLEN TUBE DISAPPEARED AND THE POLLEN GRAIN RETURNED TO THE ANTHER FROM WHICH IT HAD COME.

plates were also hand-painted in color to show first, second, third and fourth year layers of bast or phloem.

On each of the nuts riding on the finer, inner threads of each spindle, a small arc or curved strip of metal was mounted, threads of the spindles would permit, the ends of the sixteen upper arcs, with their rollers, overlapped the ends of the sixteen lower arcs and all formed a perfect circle. When the arcs and nuts moved outward away from the center of the

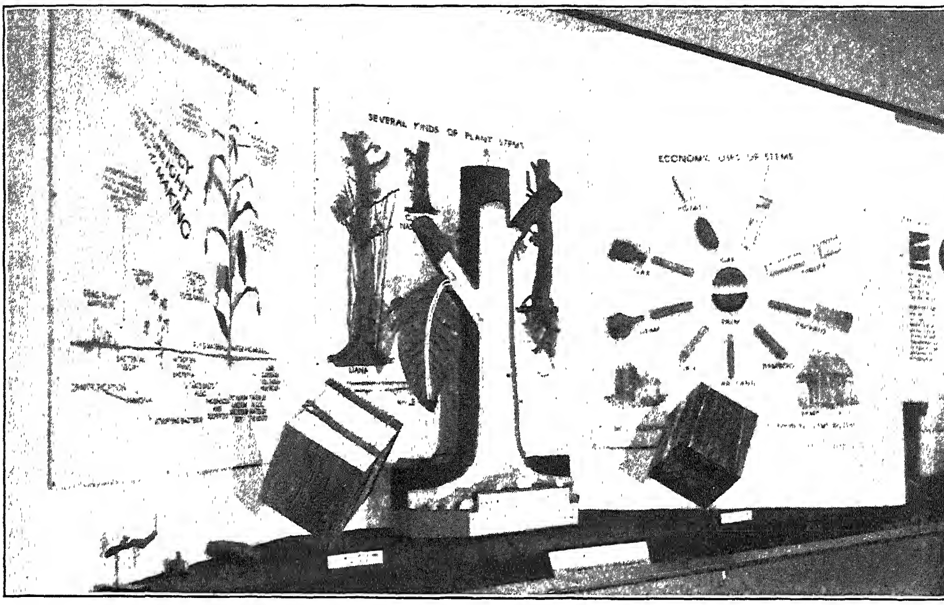

FIG. 12. STEM CIRCULATION

WAVES OF DYE MOVED UP AND DOWN IN THE GLASS TUBES OF THIS STEM MODEL TO ILLUSTRATE THE MOVEMENTS OF FLUIDS IN THE PHLOEM AND XYLEM OF THE TREE. THE TWO WOOD BLOCKS REVOLVED SLOWLY.

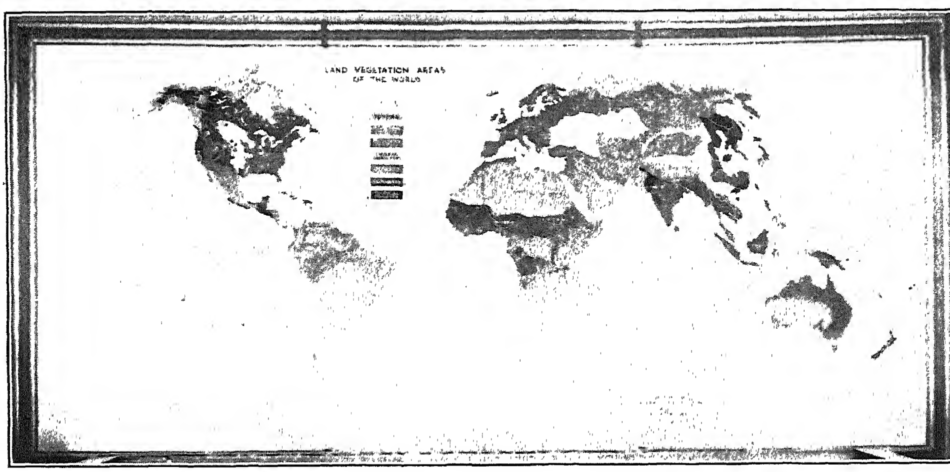

FIG. 13. MAP OF VEGETATION AREAS

HUNDREDS OF SMALL LIGHTS, FENCED OFF INTO REGIONS CORRESPONDING WITH THE DIFFERENT VEGETATION AREAS, WERE REQUIRED TO GIVE THE SEQUENCE OF ILLUMINATION DEMANDED BY THIS EXHIBIT. IT WAS PREPARED IN SPECIAL TRANSPARENT PAINT, ON FOUR VERY HEAVY SHEETS OF CARRARA GLASS.

mechanism, they still formed a quite regular circle. On these arcs or curving strips the green cell-detail of the cambium or growth layer and young xylem and phloem were painted. When the entire mechanism was collapsed to the condition preceding growth, the visitor saw only three years of bast detail, the center, showing the cell-detail of central pith or parenchyma, the primary xylem, the first, second and the third year rings of secondary wood or xylem, in ever-widening circles. Now all was provided for but the fourth year of wood. For this, rectangular strips of canvas, cut on the diagonal or bias, were fastened

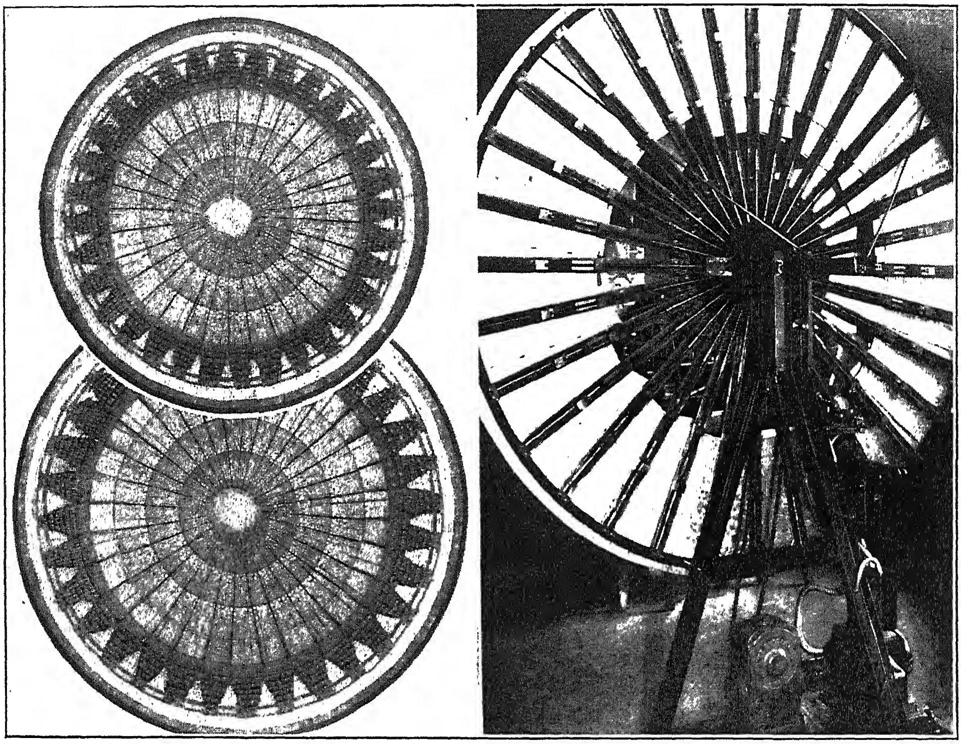

FIG. 14. GROWTH OF TWIGS

Upper left: THREE-YEAR-OLD TWIG. *Lower left:* FOUR-YEAR-OLD TWIG. BY THE METHOD OF SLIDING PLATES AND CANVASES DESCRIBED IN THE TEXT, THE ENTIRE OUTER EDGE OF THE TWIG EXPANDED TO MAKE ROOM FOR NEW XYLEM OR WOOD AND NEW PHLOEM OR BAST. THE NEW WOOD IS THE FOURTH RING FROM THE CENTER. *Right:* REAR OF TWIG MECHANISM. THE CANVASES WERE BEING ASSEMBLED WHEN THIS PHOTOGRAPH WAS TAKEN. THE CENTRAL BRONZE GEAR, THE SPINDLES, THE SLIDING NUTS, THE BASAL PLATES, THE CONTROL MECHANISM AND THE MOTOR AND GEAR REDUCER CAN ALL BE SEEN IN THIS VIEW. AN ENTIRELY ENCLOSING CASE WITH SPECIAL LIGHTING ARRANGEMENTS WAS EVENTUALLY PREPARED TO HOUSE THE EXHIBIT.

fourth year sliding under the cambium arcs.

Now it was necessary to provide for the wood or xylem. A large circular plate of thin steel was mounted in the tightly at one end, were pulled over the rollers in the cambium segments, and were held at the other or outer end by small, strong, screen-door springs, attached near the center of the mechanism.

The cell details of the fourth year of wood were painted on these canvases.

Automatic stops and reversing switches were introduced, along with a small timing motor which would put the entire mechanism into operation, once the visitor had pressed the starting button. The wiring of the model was quite complex. A great circular lighting ring was placed around the entire exhibit, so that the twig section would be illuminated from all parts of the circumference.

As the visitor approached the exhibit he found the lights on and the twig showing three years' growth of wood and bast (Fig. 14, upper left). He pressed the button. The small motor made the contact and the large motor then revolved the bronze gear. This gear turned the pinions and spindles, causing the new wood cells to develop apparently from the inside of the cambium, while the new bast cells appeared from the outer side of the cambium. This growth apparently forced the epidermis, the cortex, the pericycle and the first three years of bast to stretch outward, until at last four full years of bast and wood were visible (Fig. 14, lower left). Then the lights went out, the motor reversed and the twig returned to the three-year stage, the lights coming on at the end.

This model was excellently constructed. Only two spindles were replaced throughout the entire five months of 1933. None of the canvases were replaced, though a duplicate set was available.

This exhibit explained in clear and simple fashion a biological phenomenon previously understood by only a few of the thousands who stopped to watch it. Only animated motion pictures could tell the same story as simply as this model told it. But where a few would stop for motion pictures, countless visitors were arrested by the striking size and had their curiosity aroused by the unique appearance of the model.

Models that look like the organism or structure are not only hard to build, but are often fragile and usually prove extremely expensive. Months were spent developing ideas with a view to mechanization, only to have the plans end in the files when trustworthy estimates of construction cost and upkeep had been procured.

About these dynamic models or groups of living displays, we installed our static exhibits in the form of models, charts, panels, groups, dioramas and other displays. They rounded out the stories, but we depended upon the dynamic exhibits to catch the eye of the visitor and bring him into the group. Once he had stopped, he would often follow out the story, from the first exhibit of the group, through to the last. But it must be confessed that thousands of visitors passed by the static, carefully and even laboriously displayed exhibits, once they had seen the dynamic displays of the unit.

The "sequence of exhibits which will tell a story" idea seemed an excellent one. Many readers may remember the cell sequence which was designed (with many modifications of the original plan) to tell a brief story of the cell, its discovery, its place in nature and its structure and activities. But here few visitors followed through the entire sequence, although it contained some exquisite models, several interesting mechanisms and the histological laboratory. It had the misfortune to be placed, originally, across from the exhibit in human embryology which had tremendous popular appeal. The cell exhibit could never hope to obtain the attention it deserved. Moreover, the Microvivarium, with its living projections, had to be placed in an entirely different locality and the public rarely saw both parts of the cell story on the same day. As it was, the mechanized units of this cell exhibit drew what attention the visitors gave to the sequence, static models being passed by almost unnoticed.

As mentioned before actual counts were made to show comparative numbers of visitors pausing in front of various exhibits over a given period of time. A large, moving exhibit could be counted upon to attract at least twice as many visitors as a static exhibit, unless it had tremendous size or was very unusual in appearance. Many thousands stopped to look into the bathysphere, or to study the embryos mentioned above, though they had no motion.

Speaking models were out of the question unless the exhibits were separated by soundproof rooms. The care required for their proper functioning may be ignored, but too many visitors in the biology section were inclined to consider one or two adjoining speaking models in the category of public nuisances. Likewise motion pictures must be used sparingly unless halls are available for their presentation. The visitor will not read their explanations and tires too quickly after he has watched a few in action.

Many readers may ask whether the visitor really learns anything from a dynamic exhibit. Is it worth the expense? The answer is certainly ''yes.'' Many visitors returned again and again to see the twig grow, or to bring others to see it grow, while the questions that our guides were asked concerning such displays as that dealing with the circulation of the blood might well have taxed the learning of a professor of anatomy or physiology.

Thus we see that biological principles can be demonstrated by this dynamic exhibit method. Almost any biological subject lends itself to such demonstration if sufficient time and money are available for construction. Only when such exhibits are available will the great mass of people come to our museums and exhibitions and willingly try to learn about these basic principles and phenomena.

The Buffalo Museum of Science has purchased many of the dynamic exhibits in biology that were shown at A Century of Progress. They will undoubtedly find that these mechanisms well repay the care required to insure their continuous operation.

SNAKE BITE IN THE UNITED STATES

By Dr. THOMAS S. GITHENS

THE MULFORD BIOLOGICAL LABORATORIES, SHARP AND DOHME, GLENOLDEN, PA.

Until recent years there has existed, even among the best-informed herpetologists, a great misapprehension concerning the number of bites by poisonous snakes which occur annually in this country. In spite of the fact that we have as many as twenty-five kinds of poisonous serpents, ranging over the entire country from New England to Florida and west to the Pacific coast, there was no information on which to base even an approximate guess as to the number of accidents caused by them until these laboratories made a serious attempt to collect reports from all over the United States from physicians, health authorities and news agencies.

Hitherto the most complete summary was that of Prentiss Willson, who in 1908 gathered reports of 740 bites covering a period of almost a century. He concluded that the number of bites every year was "excessively small," probably less than 500, and that they were becoming more and more infrequent as the vipers were being "slowly but surely exterminated." The last opinion is almost certainly a mistaken one. The number of bites obviously bears a close relation to the relative abundance of snakes, and this, by a well-known law, is related to the supply of available food, which with our pit vipers consists mainly of rodents. Rats and mice increase rapidly in number when desert country is converted to agricultural, with resultant increase in the supply of grain on which they feed, and for this reason all snakes, including the poisonous species, become more abundant as land is used for agriculture, tending to disappear only in thickly settled communities, as around big cities.

Number of Bites Occurring Annually

Since 1927 we have been collecting information in regard to the frequency of bites by poisonous snakes in the United States and have been surprised by the unexpectedly large number. Particularly earnest effort was made during 1908 and 1909 by R. H. Hutchison, who gathered reports of 610 such accidents in one year. He estimated from the irregular distribution of the reports that approximately one third of all bites were included and that the total number was from 1,500 to 2,000 yearly. We have no reason to doubt the correctness of this estimate. The smaller number of reports in later years does not indicate any falling off in the number of bites but less intensive effort to gather full information.

Our information was derived from two sources. The first, and by far the more important consists in the report forms which accompany each package of antivenin, and which many physicians who have treated snake bites have been kind enough to fill in and return to us. Their assistance is hereby gratefully acknowledged. The second source of information is found in newspaper items describing bites. Table I shows the number of reports of each sort received each year.

Range and Distribution of Poisonous Snakes

As regards the distribution of our poisonous snakes, the United States may be roughly divided into 6 zones or areas, each characterized by the occurrence or abundance of certain particular species. The first zone includes New England, the Middle Atlantic States and Maryland.

TABLE I
NUMBER OF MEDICAL REPORTS AND PRESS CLIPPINGS EACH YEAR

	1927	1928	1929	1930	1931	1932	1933	1934	Total
Medical reports	95	361	369	281	210	192	164	131	1,803
Press clippings	144	249	121	46	13	0	0	0	573
Total	239	610	490	327	223	192	164	131	2,376

The only poisonous snakes are the copperhead and the timber rattlesnake. West of this is a second zone extending from western New York and Pennsylvania to Minnesota and south to Tennessee. Here the same species are abundant but associated with the rare Massasauga. A colony of Texas rattlesnakes, originating from snakes escaped from a traveling circus, has established itself in Wisconsin, but no bites have been reported from them.

The third zone includes the South Atlantic and Gulf States and the lower Mississippi valley. The copperhead and timber rattler are common, as is also the water moccasin. In the southern portion occur also our largest and most dangerous serpent, the Florida diamondback rattlesnake, and our smallest and least dangerous, the pigmy rattler. Our only native non-viperine snake, the coral snake, is also occasionally encountered here. The fourth zone comprises the Great Plains, from the Mississippi River to the Rocky Mountains. Throughout this area the prairie rattler is the most abundant poisonous form. Further south is the fifth zone, including Texas and the adjacent states, characterized by sandy regions with sage brush and cactus, and forming the habitat of the prairie dog. Here the Texas diamondback rattlesnake, our most important species, dominates the scene and is justly feared by all the inhabitants. One of the most interesting small rattlers, the sidewinder, is moderately common. Finally, the sixth zone takes in the country west of the Rockies. Here the Pacific rattlesnake is found, being especially abundant in the hills of the Sierra range. In south California many relatively unimportant rattlesnakes of narrow range, such as the sidewinder, red rattler, green rattler, bleached rattler, Mojave rattler and blacktailed rattler, are found. Of these rarer species, only the sidewinder is reported as having bitten man, apart from two bites by captive green rattlers and one by a captive Mojave rattler.

RELATIVE DANGER TO MAN

The number of bites inflicted by any species depends on three factors: the abundance and range of distribution of the species, its tendency to live in thickly settled regions and to invade gardens, farmyards and villages, and its viciousness. All three of these assume their most favorable form in the copperhead and the Texas diamondback rattler. Both species are abundant over a wide range of territory, both show a tendency to invade the neighborhood of dwellings, being the only forms which commonly enter barns and houses, and both are very vicious, striking without warning any one approaching them. The timber rattler, although occurring over the same range as the copperhead and hardly less abundant, is much less likely to be encountered in farmyards and close to dwellings and is one of our least vicious types, generally warning by rattling before striking and escaping without biting if possible. The water moccasin and the Florida diamondback, although abundant and vicious, are found over a narrower range and mostly in wild regions, so that they are a menace to hunters and fishermen, boys swimming in sequestered

streams and so on, rather than to persons who do not stray from the beaten track. The prairie rattler and Pacific rattler likewise are less prevalent in cultivated ground near dwellings. The coral snake rarely if ever bites unless handled.

Table II shows the total number of bites in man reported for each species of snake over the eight-year period from 1927 to 1934, arranged by zones. There is a total of 2,376 bites. Of these, 34 were considered as very likely due to non-poisonous snakes, because of absence of toxic symptoms or for other reasons. Six were coral snake bites and two were due to foreign snakes, leaving 2,334 accidents occasioned by native pit vipers. Of the 24 species and subspecies of North American pit vipers, only ten are reported as having bitten man, apart from bites by captive snakes.

The wide range of the copperhead and timber rattler is shown by the fact that bites by each of them are reported from all but one of the 6 zones. Most other species are largely limited to a single zone. The occurrence of bites by the Texas diamondback in all zones is accounted for by the fact that this snake is much used by showmen and circuses.

Almost twice as many bites resulted in the two southern zones as in the four northern. This is partly due to the shorter period of hibernation, partly to the greater activity of snakes in hot weather and partly to the greater abundance of snakes in warm climates.

TABLE II

Number and Distribution of Bites by Poisonous Snakes

Species		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Total
Copperhead	*A. mokasen*	147	134	250	18	142	0	691
Water moccasin	*A. piscivorus*	2*	8*	164	2	28	1*	205
Timber rattler	*C. horridus*	60	34	108	3	10	0	215
Texas rattler	*C. atrox*	4*	4*	3*	5	386	9	411
Florida rattler	*C. adamanteus*	0	0	70	0	0	0	70
Prairie rattler	*C. c. confluentus*	0	0	0	133	21	0	154
Pacific rattler	*C. c. oreganus*	0	0	0	9	3	122	134
Sidewinder	*C. cerastes*	0	0	0	1	9	7	17
Green rattler	*C. lepidus*	1*	0	0	0	0	1*	2
Mojave rattler	*C. scutulatus*	0	0	0	0	0	1*	1
Massasauga	*S. catenatus*	0	12	0	0	10†	0	22
Pigmy rattler	*S. miliarius*	0	0	73	0	0	0	73
Unidentified	*Sp.*	27	10	131	26	113	32	339
Native Pit Vipers,	Total	241	202	799	197	722	173	2,334
Coral snake	*M. fulvius*	0	0	5	0	1	0	6
Palm viper	*Bothrops Sp.*	0	0	1*	0	0	0	1
Puff adder	*Bitis arietans*	1*	0	0	0	0	0	1
Bites by poisonous snakes		242	202	805	197	723	173	2,342
Probably non-venomous snakes		17	7	5	0	5	0	34
Total of all bites reported		259	209	810	197	728	173	2,376

* Bites by captive snakes.

† May be in part *S. miliarius.*

Circumstances under which the Bites Occurred and Part of Body Bitten

These two factors are closely related, as the activity of the victim often determines the site of the bite. Rather more than half the bites are inflicted on the lower limb. In most cases the snakes have struck at a person walking past them as they lay concealed in grass or other cover, but in many instances the victim actually stepped on an unseen snake,

often at night. Almost all the remaining bites are on the hands, wrists and arms. These commonly resulted as the person was picking up or reaching for some object near which the snake lay concealed. A large proportion were received while gathering crops, vegetables, fruit, cotton, etc.; many while picking up wood or other objects, and still others while reaching into rabbit holes and similar hiding places while out hunting. Less than 1 per cent. of the bites were on the body or head.

A surprisingly large number of bites were inflicted on persons who were intentionally handling poisonous snakes. Of the 2,342 bites, 163, or more than 1 in every 15 were received in this way. Of these, 47 were in ignorant persons, often children, who picked up the snakes, not realizing their danger. Forty-eight were in professional snake catchers, about half being received while capturing the snake and half in handling recent captives. Thirty-one were showmen at fairs or carnivals, and 23 scientists studying snakes in the laboratory or extracting venom. Snakes supposed to be dead inflicted 14 bites.

Mortality from Snake Bite and Influence of Method of Treatment

Although the venom of different species of snake shows considerable variation in toxicity, the danger of death or serious consequences resulting from a bite by our pit vipers is mainly dependent on the amount of venom injected, and this in turn is closely related to the size of the snake. Thus the most dangerous of our species is the Florida diamondback, and this is closely followed by the related Texas species, which gets to be almost as large. Forms of intermediate size, such as the timber rattler, water moccasin, prairie rattler and Pacific rattler, are less likely to cause death, while the bites of small species, such as the copperhead and pigmy rattler, are rarely fatal in adults.

Venoms are tested by determining the fatal dose in pigeons and when we compare the average fatal dose for these with the average amount of venom which can be extracted by squeezing the venom glands, we obtain a factor showing the number of fatal doses in one extraction. This figure corresponds closely with the size of the species on one hand and with the percentage mortality in man on the other, as will be seen by reference to Table III.

The mortality is also markedly influenced by the method of treatment used. Many methods are in use by laymen, and these differ in popularity from one part of the country to another. Some are based on tradition, such as the splitting open of a live chicken and application of the freshly cut flesh to the wound with the expectation of "drawing out the poison." In the southwestern portion of the country, crude oil and kerosene are frequently applied. Cauterization of the wound is often mentioned. Among the better informed, application of a tourniquet on the limb above the site of the bite, followed by more or less free incision of the wound, with or without the use of suction by mouth or otherwise, is commonly practiced. Physicians often apply wet dressings of epsom salts or potassium permanganate.

Among general supportive measures, whiskey is most frequently administered, in spite of many studies showing that it does more harm than good. Aromatic ammonia and similar quickly acting stimulants may be of some value. Vegetable remedies, so much used as "specific cures" in Latin America, enjoy but little popularity in the United States. Injection of large volumes of normal salt solution or glucose solution and transfusion of blood, which are now considered the most valuable means of combating the toxemia, are still very rarely employed.

The only local measure having any

TABLE III

INFLUENCE OF METHOD OF TREATMENT ON SNAKE BITE MORTALITY

Species	Without A. V.			With A. V.			Total			M.L.D.	Average length of snake
	Total	Die	Per cent.	Total	Die	Per cent.	Total	Die	Per cent.	P. yield	
Florida diamondback...	5	3	60	65	16	25	70	19	27	1,600	100 ins.
Texas diamondback...	51	18	35	358	28	7.8	409	46	11	1,200	78 "
Timber rattler	30	9	30	184	4	2.2	214	14	6.7	890	48 "
Prairie rattler	26	5	19	128	4	3.3	154	10	6.5	600	44 "
Pacific rattler	20	3	15	114	6	5.2	134	9	6.7	700	44 "
Water moccasin	27	4	15	178	4	2.3	205	8	4	890	48 "
Sidewinder ..	2	1	50	15	0	0	17	1	6	183	30 "
Copperhead ...	150	5	3.3	542	1	0.2	692	6	0.9	470	36 "
Massasauga...	3	0	0	19	0	0	22	0	0	540	24 "
Pigmy rattler	5	0	0	68	0	0	73	0	0	10	18 "
Green rattler	0	0	0	2	0	0	2	0	0		
Mojave rattler	0	0	0	1	0	0	1	0	0		
Palm viper ...	0	0	0	1	0	0	1	0	0		
Species unknown	76	9	12	263	8	3	339	17	5		
Total	393	56	14	1,921	72	3.7	2,314	128	5.5		

Percentage figures are generally given in nearest whole number.

real value is the application of a moderately tight tourniquet, associated with free incision of the site of the bite and the swollen area, with persistent use of suction. As much as half the venom injected by the snake may often be removed before it has time to be absorbed. Of constitutional measures, apart from complete rest, which is imperative, the most valuable are injections of salt or glucose solution or transfusion of normal human blood.

Now that antivenum, a specific serum effective against the bites of our North American vipers, is available, the mainstay of treatment is the use of adequate doses of this serum. Its great value is shown by the marked reduction in mortality under its influence, the number of deaths, as seen in Table III, being reduced to approximately one fourth of that in cases not having the advantage of its use. The total death rate for all bites is reduced from 14.3 to 3.7 per cent.

Of the 72 persons dying in spite of serum treatment, 25 were already near death when the serum was first given. In 6 other cases death was occasioned by gangrene resulting from too tight tourniquets. More than half were children under 14 years of age.

SOCIAL ORGANIZATION INVENTIONS—"DANGEROUS PATENTS"

By LAURY L. WILLOF

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"The patent system, itself, is an invention for fostering inventions."—W. M. Grosvenor.

IN connection with the discussion of the status of the social inventor, initiated by the article, "Will There be an Age of Social Inventions?" by Professor Arland D. Weeks in THE SCIENTIFIC MONTHLY[1] (reviewed by Robert Cook in *Journal of the Patent Office Society*), it may be of considerable interest to recollect the now mostly forgotten fact that in the period immediately following the French revolution several patents were issued on inventions, which must be classed as social inventions.

The conditions surrounding this episode in the history of the patent system were as follows.

The patent system in the modern meaning of the term was introduced in France by the Act of 1791, which was held to be based on the Declaration of the Rights of Man (from the year 1789). This declaration reads as follows:

The Representatives of the people constituted as the National Assembly, considering that ignorance and contempt (*mépris*) of the rights of man are the fundamental causes of the public misfortunes and the corruption of the governments, have resolved to expose in a solemn declaration the natural inalienable and sacred rights of man, in order that this declaration, constantly presented before all the members of the social body, shall ceaselessly remind them of their rights and their duties; in order that the actions of the legislative power, as well as of the executive power, can at every instant be compared with the ultimate object of all political institutions, and thus become more respected, in order that the claims of the citizens, in future based upon simple and incontestable principles, shall always turn out to the maintenance of the constitution and to the happiness of all.

In consequence the National Assembly recognizes and declares, in the presence and under the auspices of the Supreme Being, the following rights of man and citizen.

Art. 1. Men are born and die free and with equal rights. Social distinctions can only be based upon the common advantage.

Art. 2. The object of all political association is the preservation of the natural and inalienable rights of man. These rights are liberty, security, and resistance against oppression.

Art. 17. Property being an inviolable and sacred right, nobody can be deprived thereof if it is not clearly required by public necessity and under the condition of fair and preceding compensation.

The introduction to the French Patent Act of 1791, which is based on this declaration of rights, reads as follows:

The National Assembly, considering that every new idea whose manifestation or development may be useful to the society belongs primarily to him who has conceived the same, and that it would be an attack upon the rights of man in their essence not to regard an industrial discovery as the property of its author; considering at the same time that the absence (*défaut*) of a positive and authentic declaration of this truth may have contributed until now to discourage French industry, conducing to emigration of many distinguished artisans and causing a great number of new inventions to pass to foreign countries—inventions of which this empire ought to have taken the first advantages; considering finally that all principles of justice, public order and national interests make it imperative to fix in future the attention of the citizens of France on this type of property by a law that consecrates and protects it. . . .

Article 1 of the same law states:

Every discovery or new invention in all branches of industry (*genres d'industrie*) is the property of its author. Consequently the law grants to him the full and entire enjoyment thereof in the manner and for the time below determined.

[1] 35: 366–370, October, 1932.

It is not to be wondered at that—in view of the statements in the declaration of rights as well as in the Patent Act itself—inventors of projects of organization considered themselves entitled to be treated similarly with the inventors of machinery and materials.

Ch. Renouard, in his "Traité des Brevets d'Invention," reports as follows about some occurrences which were the consequences of the decreed rights of man in the field of inventions:

After the promulgation of the Acts of 1791, project-makers (*hommes à projets*) imagined that they could patent every kind of financial plans.

The first patent of this kind was taken out on August 2, 1791, by Lafarge and Mitouflet for their celebrated life annuity scheme (*tontine*). Patents were taken out for tariffs, to reimburse feudal rights, credit plans, mortgage systems, banks, exchange control and guarantee bureaux for assignats. Fourteen patents of this type had been granted when the legislators decided that under the conditions (*milieu*) of public anxiety caused by the disorder and convulsions of paper money, their intervention was necessary to prevent flooding with patented financial plans. On September 20, 1792, the legislative assembly, which on the next day should have their last meeting, in accordance with a proposal of Baignoux decreed the abolition of these patents and of future patents of this type. According to the *Bulletin des Lois* this was the last act of this assembly. The decree of September 20, 1792, reads as follows:

The National Assembly, considering that the patents for inventions authorized by the Act of the 7th of January, 1791, can be granted only to the authors of any discovery or new invention in all branches of industry relating only to arts and handicrafts (metiers), that patents of invention which might be issued for financial establishments would be dangerous and that it is important to take measures to stop the effect of those already issued or that might become issued;—Decrees that the matter is urgent.

The National Assembly, after having decreed the matter to be urgent ordered that the Executive Power should no more grant patents of invention for establishments relating to finance, and should stop (supprimer) the effect of those which had been granted.

(This law was passed without discussion on the 20th of September, 1792.)

The rule of excepting plans of credit and finance from patent has been carried over into the law of 1844.

In the report before the Chamber of Deputies on the 5th of July, 1843, this rule is notified as follows:

"A second exception is pronounced by article 3 as regards plans and combinations of credit and finance.

"Patents granted to these conceptions could readily become a means of fraud and a trap against private fortunes.

It was not long before experience showed this.

As soon as the Acts of 1791 had been issued a great number of speculators, profiting by the taste of the time and the embarrassment of the treasurer, covered under patents of invention their financial combinations. Two years only had elapsed when the National Assembly, by an Act of September 20, 1792, thought it their duty to cut this evil down at the root. The preamble of the Act declared the said patents to be *dangerous* and said that it was important to stop their effects. Not being satisfied by deciding that the executive power should no longer register patents for financial establishments, the decree nullified by a retrospective disposition the effect of the patents already issued."

When the proposed law was discussed in the Chamber of Deputies on the 10th of April, 1843, the rule of exception was defended by Desmousseaux de Givre as follows:

"Article 3 provides the guarantee of public order, just as Article 1 provides the guarantee of liberty.

In 1792 the experience of the two first legislative assemblies had sufficed to make it clear to them how the credulity of the public could be abused by means of certain financial plans, certain banking projects and life-annuity schemes. . . . You all know how readily and grossly the credulity of the public can be abused by writing on a label "invention patented by royal order." The Act of 1792 would protect the citizens' fortunes against charlatinism."

In the meeting of the 11th of April, 1843, the deputy Bineau made the following remark:

"The commission will no doubt understand that when patents on financial schemes are proscribed, this is not because such patents are dangerous. They might have been so in 1792, but at present this would not be the case, because the Government is by other means completely armed against them. When they are proscribed, this is because they are still theories; it is because they are included, just as systems, methods, in a class of things which is too immaterial to be made subject to a patent for industrial invention. It is so clearly true that they are of a scientific and theoretical character that the Government has included them with the methods and principles in the same paragraph, in the same framing. The Commission only for the sake of order and grammar has made it a special paragraph."

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

PLANNING FOR WATER RESOURCES DEVELOPMENT

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THE late Justice Holmes in one of his last great opinions said, "A river is more than an amenity; it is a treasure. It offers a necessity of life that must be rationed among those who have power over it." This pronouncement, which has already become famous, may equally well be applied to the water resources of the entire nation. Water, in the atmosphere, on the surface of the earth or under ground, is the greatest mineral treasure which this, or any, country possesses. But although it is a renewable treasure, it is neither limitless in amount nor distributed equally throughout the country, nor susceptible of complete control by man.

While the inexorable operations of the hydrologic cycle have been recognized for thousands of years and are expressed in the passage from Ecclesiastes that "All the rivers run into the sea, yet the sea is not full; unto the place from whence the rivers come thence they return again"; still, the ever-continuing processes of precipitation, percolation, run-off and evaporation are neither uniform in amount nor (within narrow limits) predictable as to quantity or time of occurrence.

The character of our civilization, the development of our agriculture and industry, the welfare and safety of our people everywhere is governed more by the nature and extent of water resources than by any other factor. To plan intelligently for the development, conservation and control of this great national treasure for its most beneficial public use is certainly one of the highest services which the engineer can render.

The uses of water resources have been classified in the order of their influence upon man as follows: (1) Atmospheric moisture indispensable to organic life; (2) drinking water for man; (3) water used in agriculture and animal husbandry; (4) water as the habitat of fish and sea food; (5) water used for the generation of power, both hydro-electricity and steam; (6) water used for mechanical and chemical processes in industry; (7) water as a medium of transportation; (8) water in its effect on human settlement, especially the location of cities; (9) water as a medium for the removal and purification of wastes; (10) water as a recreational asset; (11) water as a determinant of political boundaries; and (12) water used as ice.

This enumeration of the chief uses of water immediately suggests two major conclusions:

(1) In any given region or locality, one or more of these uses is likely to be in conflict with another, and whenever the pressure of civilization upon the water resources approaches a point where no surplus water exists sufficient for all the desired uses, a determination as to relative priorities for certain uses must be made. On the other hand, surplus waters require control. Planning for use and control is clearly indicated.

(2) To plan for use and control, even on limited local areas, requires factual

data of a scientific or technical nature. The more wide-spread the region for which planning is required, the more detailed and elaborate the scientific and technical background must be. This involves an inventory of the water resources, and it must precede any adequate planning for most beneficial use and control.

In January two significant reports appeared in which for the first time in the history of this country an effort has been made to view the water resources of the nation in relation to their multiple uses and from the two aspects of an inventory and a plan just mentioned. These reports are those of the Mississippi Valley Committee and the Water Planning Committee of the National Resources Board.[1] They have been widely referred to in the press, but they should be obtained and read by many thoughtful persons if the full significance of the vital necessity for planning for the use, control and conservation of our water resources in the interest of the future welfare of the nation is to be realized. Only by such realization can the public be aroused to demand an effective continuing policy which may serve to save vast areas of our land from the destructive influences of water and conserve these great treasures for the use and convenience of man. These are not dry-as-dust government reports: they are vivid pictures of water in its relation to national life and welfare. I urge those of you who are listening to this address to obtain them from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Now, what in brief do these two comprehensively and profusely illustrated reports point out that is of immediate concern to us? Well, in the first place most of you have read of, and many of you have experienced, the effects of the great drought last year which caused such human suffering and monetary loss, in the Central States from the Dakotas southward. All of us will be affected by it in increased prices of foods if in no other way. It is a striking illustration of how water resources is no longer a local problem, but one of national scope. For several years rainfall has not only been deficient in the region mentioned, but such precipitation as has occurred has not come at the best time for crops.

In much of the vast agricultural and stock-raising region west of the one hundredth meridian precipitation is either insufficient for the needs of the uses to which the land has been put or it does not come at the right time or both. Hence, for full land utilization the water of rivers must either be stored in reservoirs in times of surplus flow for delivery in times of deficient rainfall, or it must be stored by percolation into the great natural reservoirs of the soil in what we call ground water from which it may be pumped in time of need. If precipitation is deficient for several successive years, the surface reservoirs, unless carefully planned with this objective in view, may be insufficient, or the ground-water levels may be so lowered as to cause wells to go dry, or to increase pumping costs to an uneconomical point. As ground-water levels are reduced, as soil moisture disappears, as crops fail, as the tilled land becomes moistureless and barren, dry winds take up the very earth itself and over large areas the former fertile places are for decades or perhaps forever removed from human use.

You may see, therefore, that planning for water use can not be removed from planning for land use. To plan effec-

[1] The membership of these committees was as follows: Messrs. H. H. Barrows, H. S. Crocker, Glen E. Edgerton, Henry S. Graves, Edward M. Markham, C. H. Paul, H. S. Person, S. M. Woodward and Morris L. Cooke, chairman.

tively for use of water with relation to land means that we must evaluate various possible uses of water and of land.

Let us take another example from the more humid industrial regions of the East. We have a great river, say the Ohio. Its flow is utilized for domestic water supply, for removing sewage and industrial wastes, for water used in manufacturing purposes, for production of hydroelectric power and for navigation. From time to time droughts occur which seriously deplete the flow, causing not only danger to human activities from deficiency of water, but great impairment of water quality and consequent injury to industry, and perhaps to health. On the other hand, occasionally great floods occur, causing millions of dollars loss both in direct property and health damage, and in indirect damage from interruption of transportation facilities and the numerous activities dependent thereon. The soils are eroded, fertility is lost and reservoirs and river channels become silted.

In such a river, what might a well-planned reservoir or series of reservoirs do? A lock may be placed in the dam in the interest of navigation and a power house for the generation of electricity. Obviously, the flood waters would be retarded and could be let down during periods of low flow, producing greater supply for domestic use, greater depth for navigation, greater dilution of wastes and production of power. But all these uses are not complementary. To be most effective for low water control, a reservoir should be full as much of the time as possible. If the reservoir is not to fill up with silt and lose its utility, erosion control measures must be invoked, though such measures are essential in any event in the interests of soil conservation. The degree to which the river may be used as a carrier of wastes without polluting it beyond the ability of water purification plants to deliver a safe water to the public is a matter calling for scientific study and careful river regulation. It is apparent that the maximum utility of many of our rivers in the more densely populated regions requires the highest degree of planning to properly evaluate their multiple uses to the greatest public benefit.

Turn now to our coasts. How often do we think of the numerous factors at work to impair the utility of our harbors, sounds and beaches. Silt from eroded farms tends to fill up some of our harbors and injure shellfish areas; pollution from our seaboard cities makes certain of our coastal waters unfit for bathing; the ocean waves and currents destroy or damage millions of dollars worth of property by erosion of the sandy beaches. Inlets are opened or closed with resultant effects upon the fishing and shellfish industry. Here again we must plan for these conflicting uses of coastal waters, controlling pollution and erosion where it is in the long run the economical thing to do in the interest of the national welfare.

Various other aspects of water resources use and control are important, including those of recreation and the provision of suitable environment for aquatic life. On interstate and international water problems a volume could be written, and in the reports referred to some of the more serious complications of this kind are discussed.

Comprehensive as are the reports of the Mississippi Valley Committee and the Water Resources Section of the National Resources Board, it could not be expected that within a few months a physical plan would be evolved for the actual development of the nation's water resources. What has been attempted is a broad survey of the larger problems of water use and their relation to land use in various parts of the country. A form of directive planning has been submitted, basic national water policies have been suggested and the way pointed toward future coordinated development.

The first requisite for any sound planning of water use must be accurate hydrological information. The inventory section of the report of the Water Planning Committee presents for the first time a brief but coordinated picture of our present knowledge of precipitation, run-off, ground water, evaporation, water quality and coastal waters for the country as a whole. It portrays the extent to which our waters have been used for public and industrial water supply, power, navigation, wastes removal, irrigation and recreation. It indicates the problems of flood control and drainage. It makes clearly apparent how deficient we are in exact or adequate knowledge regarding so much of this fundamental data. For this reason, it is imperative that we begin at once a far more comprehensive and scientific approach to the investigation of our water resources, involving particularly standardized and coordinated procedures for the collection, compilation and publication of basic hydrological information.

If we will earnestly promote and effectuate the absolutely necessary scientific and engineering study of our water and land problems; if we will make use of the existing and new data to plan intelligently for the most beneficial use of our water and land resources; we may then be assured that, in the words of the Mississippi Valley Committee, we shall "hand down our heritage not only unimpaired but enriched to those who come after us."

THE SARGASSO SEA

By Dr. ANSELM M. KEEFE
PROFESSOR OF BIOLOGY, ST. NORBERT COLLEGE, WEST DE PERE, WIS.

Ever since man first overcame his primitive superstitious awe of the bounding main and went down to the sea in venturesome ships, the ocean has been a stimulus to every imagination at all susceptible to the magic call of its waters. The inescapable glamor which surrounds all things maritime gives an importance to such rumors as the finding of a Phoenician galley, the raising of an imperial barge or the unearthing of a viking ship, which is entirely out of proportion to their scientific or historic value.

Certainly terms like "the Spanish Main," "the Isle of Spices," "treasure trove," "flotsam and jetsam" and "the Sargasso Sea" are a challenge to our imaginations. As usual, the less we know about them the easier it is to romance about them. Thus, shored up by fantasy, sea-legends have enjoyed longer credence than almost any other form of literary or folk tales.

Surely, of these none has laid longer claim to imagination and belief than the mysterious realm known as the Sargasso Sea. Old and new maps, even your radio globe, may still give it a localization and a name.

Let us see where it is. It lies in the North Atlantic Ocean about midway between Africa and Florida, at the center of an immense imaginary triangle, whose points would touch New York, Gibraltar and the mouth of the Amazon. At its eastern edge lie the Azores, the Canaries and the Cape Verde Islands, and at its western edge, Bermuda and the West Indies. As you will notice, it covers an area greater than that drained by the Mississippi River and all its tributaries —larger than Alaska, and, in fact, almost as large as the whole continent of Australia.

Around it, through the cold waters of the North Atlantic, courses the warm

cyclonic circulation of the Gulf Stream, which, rising in the West Indies, swings northeast along the Atlantic states, then due east to the Spanish coast, then south to form the Canary current and finally, from Africa's Rio de Oro coast, as the north equatorial current, back to the West Indies islands again.[1]

Thus, by describing a great circle in the ocean, the Gulf Stream and its continuations in the North Atlantic form the boundary of an enormous eddy, which the German scientist Haeckel wished to regard as a "halistatic area." This is a term which you will not find in your dictionary or encyclopedia. It explains what Haeckel thought of the comparative changelessness of this portion of the ocean.

Owing to the fact that wreckage, and the usual driftwood borne by those parts of the Gulf Stream which are nearest this eddy, gradually float off into the Sargasso Sea, there arose a popular belief that its surface was studded with the derelict ships of all the centuries from the time of Columbus to recent years. They were furthermore supposed to be wedged together in an impenetrable mass of seaweed, which had likewise been swept into this eddy from the Gulf of Mexico and the Caribbean shores, where it originally grew.

This is just a tall story, however. Ships traveling from New York to the Guianas, to Brazil and to Africa, pass directly through the region. They do report occasional large masses of floating weeds, it is true, but no more than the usual number of derelict ships and wreckage which may be seen or expected anywhere else on the high seas.

The behavior of the drifting sea or—as it is commonly known—"gulf" weed is peculiar. At times the floating masses may come together to form great undulating golden yellow prairies. One mass has been reported to have been by actual measurement seven and one half miles long, and one half a mile wide.[2] It was so thick that sailors who set out to capture a hawksbill turtle sleeping in the tangle found their ship's boat inextricably caught, and they had to be hauled off by a rope from another boat.

Such heavy masses of the tangled seaweed are not always the case. Under the action of wind and waves they may break up into the long windrows familiar to seafaring people, which float in the ocean in parallel lines more or less evenly spaced, like the half-raked hay in a farmer's field. It is not surprising then that all reports regarding the nature and the amount of weed seen in the Sargasso Sea vary considerably. No one, however, denies the antiquity of their presence. Columbus encountered them and his sailors feared their diminutive vessels would be impeded by them. This is not hard to understand if we remember that the mats of growing weed may in some seasons become quite thick. At other seasons, however, they may be fairly thin, and in some cases they may even quite disappear, although this recurring disappearance and reappearance has not been satisfactorily explained, as we shall soon see.

There are only two well-known varieties of *Sargassum* floating on the open ocean. One form is more or less compact and bushy, the other more slender and delicate. Both have several easily distinguishable points in common with the related types of the weed which grow along our ocean shores. They are a much-branched, twiggy sort of plant, up to 18 or even 24 inches in height, with many golden green to greenish brown slender leaves. In the axils where the leafy outgrowths are attached, as well as along the stems, there are berry-like structures, filled with gas, which act as floats to support the plants in the water.

In the open ocean reproduction is

[1] J. Murray and J. Hjordt, "Depths of the Ocean," p. 194, Macmillan, 1912.

[2] *N. Y. Zoological Soc. Bulletin*, 28: 3, 67, May, 1925.

purely vegetative, growth occurring, as it does in land plants, at the tips of the stems. The shore plant does not have roots, but when very young attaches itself to the rocky bottom by several fine outgrowths which later mature into a hard, woody, hold-fast. There are over one hundred of these various forms of attached *Sargassum* growing in more or less deep waters along ocean shores throughout the world. Such attached forms have both vegetative and sexual types of reproduction, but the latter characteristic is lost as soon as the plants themselves become detached or branches break off and float freely in the water. This is a fact one must remember, as it has a direct bearing on one of the challenging mysteries of modern botany and oceanography.

Students of animal life, zoologists and ecologists particularly, have discovered to their delight that the undulating masses of floating seaweed are inhabited by numerous forms which either grow attached to the plants or make their homes or hiding places in the spreading branches, safe from the attacks of larger and more powerful aquatic enemies.[3] The attached forms range from microscopic animals too minute for the naked eye, all the way up through the hydroids and moss animals to the mollusks. The free-swimming types which hide in the branching masses consist mainly of crabs, shrimp and many forms of fishes (especially the curious pipe-fish and the equally curious but better known sea-horses).[4]

Perhaps the most fascinating scientifically of all the denizens of the sea-borne weed-masses are the recently discovered larval forms of the European and the American freshwater eels.[5] It is here that mature land eels migrate to meet, mate and die. It is here that the unusual young of both kinds are born, here they grow until they reach the "elver" stage, and from here they begin their long journeys through the trackless wastes of ocean back to the homes of their parents in the rivers and streams of Europe and America.

Two theories have been proposed as an explanation for the vast mass of floating weeds on the Sargasso Sea.[6] One is that they are merely the plants that have been torn from their moorings along the West Indian coast and washed out to sea on the surface of the Gulf Stream. This is a very plausible theory, but like the report of Mark Twain's death, unfortunately for its credibility the ocean-borne varieties of *Sargassum* have not yet been found growing attached anywhere in the Gulf of Mexico or in the Caribbean Sea. Another puzzling fact is that a recently reported estimate placed the total weight of Sargasso Sea weed at ten million tons.[7] If only the parts detached from shore forms are supposed to contribute to this huge mass, there should be a much larger growth of *Sargassum* in our southern waters than has yet been detected.

The alternate theory explains the presence of the sea-borne weeds on the supposition that they have been present in the Sargasso Sea from primitive times and that by a process of vegetative growth they have continued to reproduce themselves through the ages. This theory is equally plausible, but the almost complete disappearance of the plant at some seasons still remains a natural mystery.

Of course, it may very well be that certain observations made on the famous "*Arcturus* Adventure" ten years ago really do corroborate another set of ob-

[3] Wm. Beebe, "Galapagos," pp. 11–16. Putnam's, New York, 1924.

[4] W. Beebe, "Beneath Tropic Seas," p. 24. Putnam's, New York, 1928.

[5] W. Beebe, "The Arcturus Adventure," p. 22. Putnam's, New York, 1926.

[6] G. Fowler and E. J. Allen, "Science of the Sea," p. 190. Clarendon Press, Oxford, 1928.

[7] *Science News Letter*, 26: 713, 365, December 8, 1934.

servations made by the Swedish naturalist Osbeck, nearly two hundred years previously. Osbeck noticed that the plants do not always grow at the surface.[8] Part of the time they floated rather deeply submerged. Strangely enough, Dr. Beebe's log of the *Arcturus* mentions that on his return trip from the Galapagos about the middle of July that year much new weed was also discovered floating deeply submerged.[9]

Dr. Beebe further mentions a fact, familiar to all who have studied the plant, that *Sargassum* remains fresh near the growing tips of its fronds, but that the older portions of the stems die, break off and disappear.[10] It may very well be that in certain seasons, the older portion of the plants having sloughed off, the tips (on which the gas-filled floats have not been developed) sink into the colder subsurface waters and remain there until gradually the increasing numbers of newly developed floats bring them to surface again. This would account for the apparent seasonal disappearance of the bulk of the weed and its later reappearance.

Whatever the explanations that have been, or may be, offered, we may be sure that our knowledge of this fascinating oceanic problem is still in its infancy. It is one of the unsolved riddles of the high seas. Until it has been much more thoroughly studied out on the ocean, through every month and season of the year, it will remain another example of Mother Nature's mysteries—the part of those unanswered questions of our universe whose ultimate solutions are the not always so romantic duty and the province of biological science.

[8] S. G. Gmelin, "Historia Fucorum," St. Petersburg, 1786.

[9] "Arcturus Adventure," p. 421.

[10] "Arcturus Adventure," p. 7.

HOW PLANTS FIGHT DROUGHT

By HOWARD E. PULLING
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DROUGHT is ugly. It produces immediate ugliness and it begets a further ugliness that may, as man measures time, last forever. Even the word is ugly. Look at the printed word "drought." Try to pronounce it slowly. You immediately become conscious of the snarl in that gutteral "gh," the snarl that one feels in the dry winds when the sky becomes brazen and the leaves begin to curl. It is the snarl of a hidden menace, of a challenge to a fight that is not a combat, for, during a drought, life does not fight an opponent, it fights itself: it fights its own prodigal tendencies; it fights to make itself use what it has sparingly, to make itself endure yet one more day.

In this fight for life, plants are the shock troops. Indeed, it is impossible to define drought except in terms of its effects on plants. It can not be defined in terms of rainfall.

For instance, the eastern part of the state of Washington receives practically no rain during the summer months, but the farmers there do not call this drought. They would receive no sympathy if they did, for they raise about twice as much wheat per acre as do the farmers in western Kansas, whose soil is just as fertile, who get about the same amount of rain per year and who get it well distributed during the growing season. No, drought can not be defined in terms of rainfall.

Suppose we say, "A drought is a period during which plants suffer for lack of water."

That sounds complete, but is it?

Would you say there was a drought if you observed plants in your garden that lacked water? You know you would not.

Perhaps the biggest question-mark that emerges from this definition is, "What *kind* of plant?" For plants are neither simple nor alike. They are complicated enterprises that have been slowly developing for thousands and thousands of years. Because they have developed under different conditions, perfecting different ways of meeting competition and the innumerable difficulties presented by a constantly changing world, they have produced so many combinations of differences in behavior and appearance that no man can hope to call more than an insignificant fraction of them by name. That these countless differences, though subtle, are yet decisive, we learn when we try to grow them. What is intolerable drought to a tough-looking plant like English ivy suits a snapdragon so well that it produces its delicate-looking flowers in abundance.

You see, drought-resistance can not always be judged by appearances. Different plants meet the problem of drought in different ways, yet the basic problem is common to them all.

All green plants are manufacturing establishments and obtain their raw materials from their surroundings. From these raw materials they make many things, among them food. Every living thing requires food—food from which to obtain the energy for keeping alive, still more energy for growing, more still for working, and yet more to store for their future and that of their offspring. This food is made chiefly from two substances: water, obtained from the soil, and carbon dioxide, from the air.

Now, this is only one of the many uses of water. Another important one is that of inflating all the cells in the soft parts of the plant, so that, like inflated tires, they can support loads placed upon them. If the amount of water in the plant falls too low, the cells become flaccid and the leaf or young stem wilts.

Thus the manufacturing plant faces a dilemma in building its factory. On the one hand, it must always hold enough water for the mechanical requirements of support and growth. On the other hand, if it can not obtain enough carbon dioxide, it can not store food for the future, or, lacking more, it can not build new tissue, and if it lacks too much it can not even remain alive. Herein lies the dilemma: wherever carbon dioxide can enter, water can leave. The drought-resistance of a plant depends upon the effectiveness with which this dilemma is met.

The common plants with which we are familiar form a more or less waterproof covering over the older parts of the roots, over the stem and, except for microscopic pores, over the leaves. Thus the roots may absorb water through their tips, and the leaves absorb carbon dioxide through the pores. If the plant is like some of the willows and has no mechanism by which these pores open and close according to conditions, it must live where it is never difficult to obtain plenty of water. It can not withstand the mildest of droughts.

At the other extreme are plants like the cactus and the Austrian pine. When conditions are such that the factory must close, when no food-manufacturing is possible, they really close the factory. They close it so completely and effectively that they are as safe as seeds.

That is unemployment insurance carried to the limit. The food-manufacturing cell that works for a cactus or an Austrian pine has apparently been guaranteed for its entire life against loss of its job because of shutdowns.

Not so those that work for coleus plants. Let a coleus become suddenly startled by dryness about its roots and it

will discharge every food-manufacturing worker so promptly that morning finds the plant a bare pole with the leaves in a heap at its base.

Other types of manufacturing plants do not lose their courage so quickly. The courage of some, like the touch-me-not or the pumpkin, is but blind, hopeful courage. They are not resourceful; they operate as long as they can and go bankrupt when they must. But others do have resources. Some, like the snapdragon, concentrate their cell-sap so that less water will evaporate when the pores are open. What changes this may make in the way the cells live, no man can say, but there must be changes, for this concentrated sap becomes more and more poisonous the more concentrated it becomes. For many kinds of plants this program would be fatal. Perhaps that is what happens to the fesque grasses. Many a lawn of fesques has looked well after a dry summer, but died before spring. Perhaps the owner attributed this to cold, but the damage was really done before, and the plants died in the latent condition.

However, not every kind of plant forces the food-manufacturing cells to take such risks as these, while the cells in the roots that should be finding water sit day after day with their feet in the same place. No, indeed. The first thing done by them is to put the fear of the future into those root-cells and get those feet into motion. Many of the drought-hardy members of the grass family try this as one scheme to save the business.

This is apparently the reason that in eastern Washington wheat grows better with practically no rain during the growing season than it does in western Kansas, where the rainfall appears to be well distributed. In Washington the rain falls during cool, cloudy weather. But little evaporates. The rest is stored in the soil. When spring wheat is planted in April or even in May, the young plants find moisture near the surface. As the summer advances and becomes drier and drier, the roots grow deeper and deeper, finding water all the time.

Unfortunately, when the acquisitive instinct is aroused in a living creature, it is likely to exercise none of its faculties except those helping it to get what it starts after. Roots are no exceptions. In Kansas, hot, dry, windy weather alternates with the rains. Much water evaporates. The rest is near the surface. The eager, go-getter roots, dominated by the single purpose of obtaining water, grow toward that surface and—a dry period kills them.

We lawn-owners should remember this, for the roots of our grass will do the same thing. Water that penetrates dry soil does not distribute itself evenly. It travels downward for a distance that is determined by the amount of water applied. Within that distance the soil is very moist. Below it, and the line is sharp, it is dry. So if you can not apply enough water to wet the soil to a depth of several inches, it is better not to water at all.

No plant has devised a perfect method —neither orthodox methods like these that have enabled plants to survive everywhere throughout great areas of country, nor the little, tricky schemes that work only under some special set of conditions. But we must leave this plant question-mark, for others also appeared when our definition exploded.

Such another one is the drought question-mark. We have just seen that there are different kinds of droughts: in Kansas the drought is generally below ground, whereas in Washington it is above ground. In most northern dwellings, there is an above-ground drought in the winter, but it is a dark drought, not a drought full of bright sunshine, as in Washington.

Also, there may be cold droughts as well as hot droughts. When a North-

erner talks of plants being winter-killed, he generally thinks that they die of cold. This is rarely true for any but tropical plants. For instance, those evergreens transplanted this fall have damaged roots. Unless they are given extra amounts of water just as long as the ground can absorb it, they may enter the winter without enough to last them until spring. When what Chaucer called the "drought of March" arrives, with its bright sun and high winds, the last of their inadequate store will vanish into the air, and, almost over night, they will turn brown and then probably die.

Wind and sun—what a terrible combination for a plant with too little water. With sun to warm the air and enable it to hold more water, and with wind to move water-vapor away, to remove it from every pocket and crevice of the surface soil and from every pore of the plant, to bend and twist the leaves until every particle is literally wrung from them, how can a plant make food if the soil is too cold or too dry?

Tests by the Forest Service show that windbreaks in Kansas and Nebraska reduce evaporation in their lee by as much as 70 per cent. Though this effect decreases with distance, yet it was measurable about twenty times as far from the windbreak as the windbreak was high.

That is one of the reasons for that huge series of windbreaks that are to be built from North Dakota to Texas. Built of trees, some evergreen and some deciduous, trees that will establish themselves as permanent residents, that have proved that they can build up reserves that will tide them over the hot droughts and the cold droughts, these windbreaks of the big shelter-belt can offer protection to the little high-speed, quick-production factories that the farmers want to plant.

That Kansas wheat and the other plants that we hope will soon be growing near it will have a better chance against the water-robbing wind, every year. And in the drought years, the little plants can last longer, something can be salvaged by the farmer, but above all the soil will be left.

For this is that further ugliness that the drought can beget, the ugliness that can last beyond the traditions of man. When the plants have died or been harvested, when their roots no longer hold the soil together, and their tops no longer break the force of the wind near the surface, the soil begins to move. The lighter particles swirl upward into the air, to be carried, as in the dust-storms of last November and May, thousands of miles away. The coarse particles slide over each other and, in the bad drought years, the surface soil travels like the dunes of the seashore, leaving desolation behind, a desolation that does not always end when the drought ends, for when the fertile top-soil is gone it can not be renewed by man. Only the slow, time-forgetting processes of nature may some day, far in the future, produce again the prairies that many betrayed.

These trees can not conquer drought, they can but endure it. But by enduring it, by merely remaining in place and living, they can temper the droughts of the future and prevent some of their consequences.

If man will then but do his part.

If he will make his methods of cultivation fit the country and the emergencies of the country. If he will remember that this soil remained through all the storms and droughts of the centuries before his ancestors found it, because, and only because, the prairie plants kept the wind from it. If he will remember this and refrain from cultivating those parts of this vast domain that should be in grass—his days and the days of his children will be long in the land that the prairie grass gave him.

DR. HERBERT S. GASSER

DIRECTOR OF THE LABORATORIES OF THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH.

THE PROGRESS OF SCIENCE

THE NEW DIRECTOR OF LABORATORIES OF THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

THE appointment of Dr. Herbert S. Gasser as director of laboratories of the Rockefeller Institute for Medical Research will seem particularly fitting to those who are familiar with his training and scientific capacities. He comes of scientific parentage, his father having been a physician of talent. He took a baccalaureate degree at the University of Wisconsin in 1910 and then entered the medical school of the same institution. Physiology at once attracted his profound interest and for two years he served as instructor in that department and there began his research career. In 1915 he completed his clinical years of medicine at Johns Hopkins. Returning to Wisconsin he spent a year in the department of pharmacology. He then entered the department of physiology at Washington University Medical School, St. Louis. During the war he spent some time in the Chemical Warfare Service. In 1921 he became professor of pharmacology at Washington University, and in 1931 he was chosen professor of physiology at Cornell as successor to Professor Graham Lusk. As student or colleague he has served with Meek, Eyster, Loevenhart, Howell, Erlanger and Hill. He has spent two years abroad in the laboratories of University College, London, and the Sorbonne in Paris. These details of his career are mentioned to emphasize the wide training and varied experience he brings to the support of his new duties.

At no time has Dr. Gasser ever divorced himself for one instant from his laboratory researches. They began in his student days and have constantly increased in significance, volume and importance. His earliest work was on cardiac nerves, coagulation, mechanisms of oxidation in the living body, blood volume and traumatic shock. In later years his interests have centered on the problems of muscle-nerve physiology. With Erlanger at St. Louis he achieved distinction as one of the outstanding American electrophysiologists. His contributions on the development of the cathode ray oscillograph for physiological purposes, nerve conduction as related to diameter of fiber, the refractory period of nerve, the nature of nerve conduction, heat production and viscosity in muscular contraction, the effects of rapidly repeated stimuli to nerves and cord potentials are known to all students of muscle-nerve physiology and have made their author an international figure in his field. These researches have all shown a careful evaluation of data and a close reasoning which speak for a high degree of scientific ability. In addition Dr. Gasser has served as an officer of the American Physiological Society and as associate editor of the *American Journal of Physiology* and *Physiological Reviews*.

Under the able leadership of Dr. Simon Flexner the Rockefeller Institute of Medical Research has continually exerted a profound influence on American medical science. There can be no doubt that with Dr. Gasser's appointment this influence remains in safe and sound hands. His insight into the worthwhileness of technique and the true significance of biological discoveries have always made him useful and distinguished among his colleagues. His activities and usefulness will now radiate out from the fundamentals into all the applications of medical science. It is this opportunity for continual expansion which makes the Rockefeller Institute a national institution and its director a scientist of not only national but international influence.

WALTER J. MEEK
PROFESSOR OF PHYSIOLOGY,
UNIVERSITY OF WISCONSIN

MEDALISTS OF THE NATIONAL ACADEMY OF SCIENCES

THROUGH the generosity of its members and others interested in science a number of trust funds have been established in the National Academy of Sciences during the past seventy-two years. Three of these trust funds—the J. S. Billings, the Alexander Agassiz and the George True Nealley Funds—amount to $91,868.94 and are for the general purposes of the academy; five of the funds—the Alexander Dallas Bache (researches in physical and natural sciences), the O. C. Marsh (natural sciences), the Joseph Henry (original research in science), the Wolcott Gibbs (chemistry) and the Benjamin Apthorp Gould (astronomy) Funds—total in amount $145,-708.94 and are for the support of original research in the special fields designated by the donors; ten of the funds—the James Craig Watson (astronomy), the Henry Draper (astrophysics), the J. Lawrence Smith (meteoric bodies), the Cyrus B. Comstock (physics), the John Murray (oceanography), the Marcellus Hartley (public welfare), the Daniel Giraud Elliot (zoology and paleontology), the Charles Doolittle Walcott (Cambrian and pre-Cambrian life), and the J. J. Carty (distinguished accomplishment in any field of science within the scope of the Academy) Funds—amount to $112,606.50 and are intended for the support of research work in designated fields of science and for the encouragement of research by awards of medals to investigators for outstanding accomplishments in science. The academy has the task, once in each five years, of selecting for Columbia University the recipient of the Barnard Medal (physical and astronomical science). In addition to these funds there is a large endowment fund given by the Carnegie Corporation of New York for the purposes of the National Academy of Sciences and of the National Research Council.

The total number of scientists to whom medals have thus far been awarded by the academy is ninety-nine. The medals are not, however, equally distributed among the sciences; each trust fund from which medals are awarded states the field or fields of science in which its recipients must be distinguished. Four of the trust funds are for the support of researches in astronomy; from three of these funds medals are awarded, with the result that thirty-three of the ninety-nine medalists are astronomers. Ten medals have been awarded to physicists; fifteen, to zoologists; ten, to paleontologists; two, to investigators of meteoric bodies; thirteen to oceanographers; fourteen to men who have won distinction in public welfare service; one, to a geologist; and one, to a distinguished worker in science and engineering. No medals have been awarded to investigators in mathematics, chemistry, botany, physiology, pathology, bacteriology, anthropology or psychology for the reason that no provision is made in the existing trust funds for honoring representatives from these fields which cover six of the eleven sections into which the academy membership is divided. It is hoped that in the future this inequality may be removed by the establishment of additional trust funds.

At the annual meeting of the National Academy of Sciences held from April 22 to 24, 1935, in Washington, four medals were awarded. The Agassiz Medal from the John Murray Fund was awarded to Haakon Hasberg Gran, professor of botany at the Kongelige Frederiks University at Oslo, Norway, in recognition of his contributions to knowledge of the factors controlling organic production in the sea and of the relation of vegetable plankton growth to the distribution of nitrates and phosphates in sea water and to oceanic circulation. The presentation address was prepared by Dr. Henry B.

Bigelow, director of the Woods Hole Oceanographic Institute and chairman of the committee on the John Murray Fund, and was read, in his absence, by Dr. Douglas Johnson, of Columbia University. In the absence of Dr. Gran the medal was received for him by the Honorable Wilhelm Munthe de Morgenstierne, the minister of Norway.

The Henry Draper Medal was awarded to John Stanley Plaskett, director of the Dominion Astrophysical Observatory at Victoria, British Columbia, in recognition of his able and consistent labors in stellar radial velocities and related studies, energetically pursued for nearly thirty years. The presentation address was made by Dr. V. M. Slipher, director of Lowell Observatory and chairman of the committee on the Henry Draper Fund. Dr. Slipher stated that Dr. Plaskett merited recognition not only for his original contributions to science but also for his successful efforts in persuading the Canadian National Government to erect the great Dominion Astrophysical Observatory, which has a position of high repute among the world's leading observatories. In the absence of Dr. Plaskett, the medal was received on his behalf by Dr. Frank Dawson Adams, foreign associate of the National Academy of Sciences from Canada.


DR. J. S. PLASKETT


AUGUST VOLLMER


JAMES P. CHAPIN

The Daniel Giraud Elliot Medal and Honorarium of two hundred dollars for 1932 was awarded to James P. Chapin, of the American Museum of Natural History, New York, N. Y., in recognition of his work entitled: "The Birds of the Belgian Congo," Part I, published as a *Bulletin* of the American Museum of Natural History in 1932. The presentation address, prepared by Dr. F. M. Chapman, was read by Dr. Ross G. Harrison, chairman of the committee on the Elliot Fund. In this address the publication is described as the "work of a man exceptionally qualified by desire, natural gifts and experience gained in nature, the museum and the classroom; it records in detail observations on habits and distribution, the result of prolonged field work; it discusses questions of taxonomy and of nomenclature from the standpoint of the skilled systematist who has access to many specimens and is familiar with the literature of his subject, and it treats with the authority of the trained biologist those problems which arise in attempting to explain the relation of an animal to its environment." Dr. Chapin received the medal in person and expressed hearty appreciation of the honor conferred upon him.

The Public Welfare Medal of the Marcellus Hartley Fund was awarded to August Vollmer, professor of police administration at the University of California in Berkeley and for many years chief of police of Berkeley, in recognition of his application, in police administration, of scientific methods to crime detection and to crime prevention. The presentation was made by Dr. Max Mason, president of the Rockefeller Foundation of New York. Dr. Mason pointed out that Mr. Vollmer, through many years of effort, "has shown the way to the elimination of graft and spoils in police administration, has elevated the standards of personnel, and inspired his coworkers with pride in, and ambition for their profession. He has stimulated the search in all fields of science to bring them to bear on the problems of crime detection and prevention. It is not too much to say that he has been instrumental in the veritable remoulding of a profession." In the absence of Mr. Vollmer, the medal was accepted for him by the home secretary of the academy.

The award of these medals was made at the annual dinner of the academy by its president, Dr. William Wallace Campbell, on the recommendation, in each case, of the committee on the trust fund which made the award possible.

F. E. Wright,
Home Secretary

MOSES MAIMONIDES, PHYSICIAN AND SCIENTIST

Scientists and philosophers the world over are celebrating this spring the eight hundredth anniversary of the birth of Moses Maimonides, famous medieval philosopher, theologian and physician. Rabbi Moses ben Maimon, best known by his abbreviated name of Rambam, was born in Cordova on March 30, 1135. It is interesting to note that the city of Cordova has this year officially decreed a general celebration in honor of her famous son, offspring of a people whom the Spanish burned and butchered and finally expelled *in toto* from the land. Maimonides is known to history as a great Hebrew scholar, as the greatest Jewish philosopher and the direct forerunner of Spinoza, and as a great physician and scientist. It is in the last capacity that a brief reference is made to Maimonides in this journal.

Maimonides excelled in both the art and science of medicine. He was the leading clinician of his time, as attested by his learned contemporaries and by the fact that he became court physician of Saladin, the greatest of all sultans. It is well known that Richard the Lion-hearted and Crusader tried but failed to induce Maimonides to desert his royal


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Saracen patron. The character of Al Hakim, the physician, so beautifully described in Sir Walter Scott's novel, "The Talisman," is said to have been inspired by the living example of Maimonides.

The works of Maimonides as a medical scientist number about twenty, which may be classified as follows: (1) expositions and commentaries on older authorities; (2) works of a hygienic character; (3) works of a physiological and pharmacological nature, especially his *De Venenis,* or treatise on poisons; (4) treatises on special subjects, such as gout, asthma, accidents and mental diseases; and (5) *De Causis et Indiciis Morborum,* or "Etiology and Pathology of Diseases."

Judged by the progress of medical science and art, Maimonides' outstanding contributions were many. (1) He studied disease from the etiological and causal point of view, on the one hand, and examined the pathological changes produced by disease, on the other. (2) He laid great emphasis on the importance of preventive medicine and hygiene. (3) Throughout his works he stressed the importance of dietetics, proper balance between rest and physical exercise, the value of fresh air, sunshine and salubrious climate and the inescapable and inseparable connection between morality and physical well-being. (4) Disregarding the traditions of physicians before him, Maimonides championed simplicity in pharmacotherapy and recommended simple prescriptions instead of the shotgun variety employed by many physicians from his time until now. (5) He repeatedly emphasized the paramount value of *Vis Medicatrix Naturae,* or the curative power of nature and warned physicians against abuse of drugs, the action of which they did not understand. (6) He constantly taught the importance of cultivating *Mens sana in corpore sano,* or "a healthy mind in a healthy body." (7) He discussed the treatment of wounds sustained in accidents in a very rational and up-to-date manner and wrote a most interesting treatise on rabies. (8) Finally, he recognized the absolute necessity of combining the study of science with the humanities in order to reap the benefits of scientific research and discovery. Maimonides belonged to that select group of intellectual aristocrats and captains of the mind of whom a recent critic has said, "The most civilized minds are those of scientists who have had the energy and the curiosity to master the humanities." In this respect a striking parallel can be drawn between Maimonides and the great scientific genius, Michael Faraday, who also maintained a laboratory and an oratory.

A still more striking parallel can be pointed out between Maimonides as physician and William Osler, the greatest physician America has produced. Both Osler and Maimonides believed in combining the practice of medicine with medical research. Both considered the prevention of disease more important than its cure. Both stressed the importance of fresh air, sunshine, rest and exercise as physical agents in the treatment of disease. Both relied on *Vis Medicatrix Naturae* and advocated simple prescription writing to such an extent that they have sometimes been termed therapeutic nihilists. Both preached and practiced sane morality and sex hygiene as the foundations of a healthy body and mind, and both strove to harmonize science with the humanities for the happiness and welfare of mankind. We may well give Maimonides the title of "William Osler of Medieval Arabic and Hebrew Medicine," and in paying this tribute to his memory we must not forget that he antedated Osler by some seven hundred years.

The so-called prayer of Maimonides is a fitting conclusion to this brief comment, particularly in these days when there are those who reject the achievements of such physicians as Jenner, Koch, Virchow, Ehrlich, Neisser, Wasser-

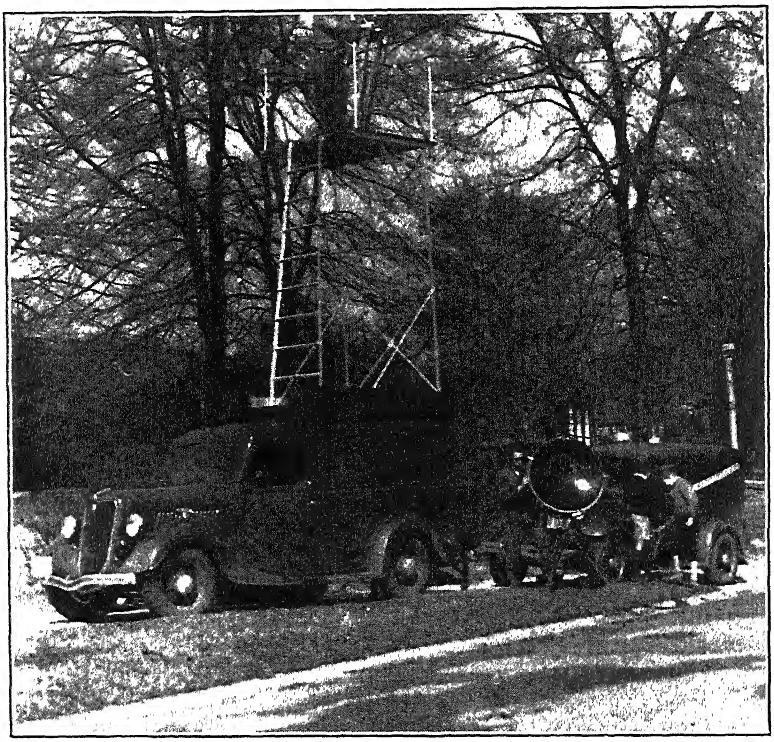
mann and von Behring because of their connection (real or fancied) with that great race which gave us the Rambam.

And now I turn unto my calling;
Oh, stand by me, my God, in this truly important task:
Grant me success! For—
Without Thy loving counsel and support,
Man can avail but naught.
Inspire me with true love for this my art
And for Thy cre-a-tures.
Oh, grant—
That neither greed for gain, nor thirst for fame, nor vain ambition,
May interfere with my activity.
For these, I know, are enemies of truth and love of men,
And might beguile one in profession
From furthering the welfare of Thy creatures.
Oh, strengthen me!
Grant energy unto both body and the soul,
That I may e'er unhindered ready be
To mitigate the woes,
Sustain and help,
The rich and poor, the good and bad, the enemy and friend.
Oh, let me e'er behold in the afflicted and the suffering,
Only the human being!

DAVID I. MACHT

THE 1935 CORNELL-AMERICAN MUSEUM ORNITHOLOGICAL EXPEDITION

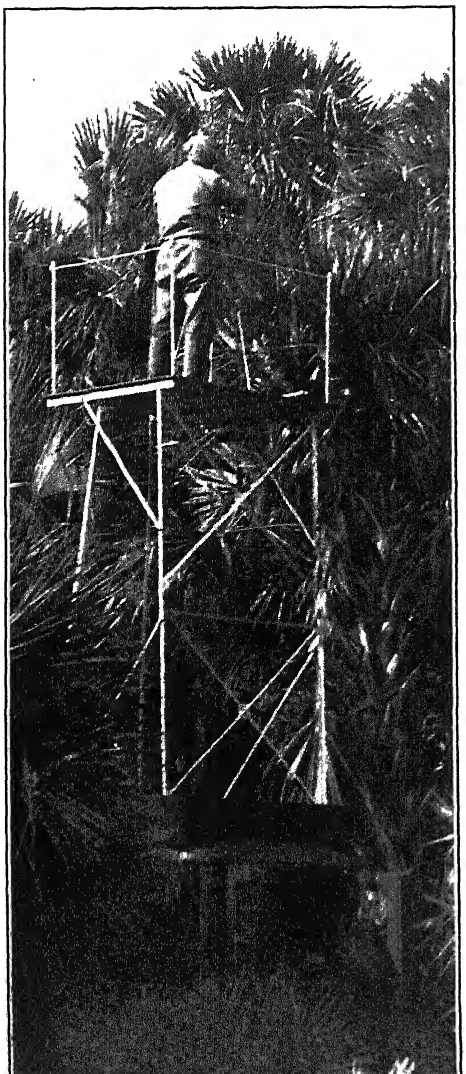
THE 1935 ornithological field expedition for the photographing and sound recording of native American birds is a joint undertaking of Cornell University and the American Museum of Natural History. Dr. Arthur A. Allen, professor of ornithology at Cornell, who is leading the group, is giving his especial attention to the photographing of birds in their natural surroundings, while Paul Kellogg, instructor of ornithology at Cornell, is in charge of sound recording. The plan is to be in the field about six months during the early part of the year,



THE SOUND AND PHOTOGRAPHIC TRUCKS

and a large part of the United States east of the Rocky Mountain divide will be visited. Much of the time will be spent in the southern and southwestern tier of states.

Several uses will be made of the material that is being acquired. A primary object is to make records of the cyclical and disappearing species so that these may be preserved when the subjects are no longer available. Ever since it has become feasible to make film recordings in nature of bird voices, the writer has been collecting the records of the songs of American birds. This collection should be enlarged materially by the addition of the material now being secured. The uses of sound film records are many. Foremost, it offers material for a concrete method for the study of bird song. The sound track on the film

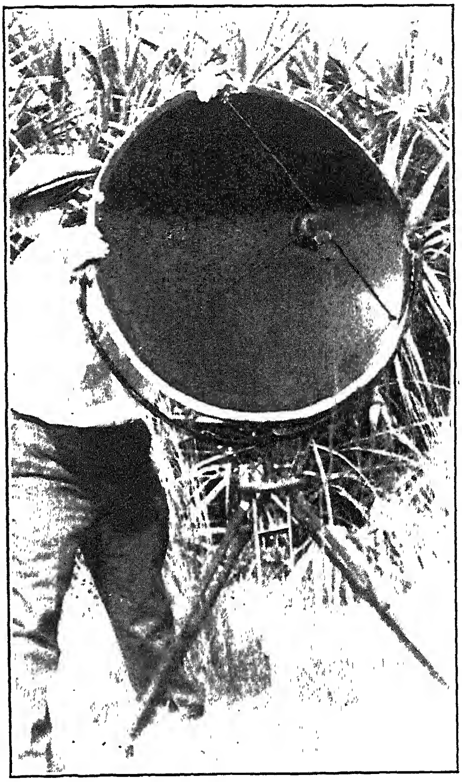


PROFESSOR ALLEN FOCUSING A MOVING PICTURE CAMERA ON THE COLLAPSIBLE PLATFORM

THE PARABOLIC REFLECTOR IN OPERATION

shows very clearly the exact pitch, quality and tempo of the song. Under a low-powered microscope the song can be carefully studied and analyzed. Heretofore this has not been possible, and the bird song student has had to rely entirely on auditory impressions. An objective medium of study is now available. In addition, the sound records can be transferred from film to phonograph disks, and some of them have already been made available for use in nature study in the elementary and secondary schools, and in scout groups, etc. The material that is being collected can be used for making additional phonograph records. Combining the motion pictures which are being taken with the photographed sound is entirely possible, and in this way a series of bird sound motion pictures is being built up.

Since the commercialization of sound motion pictures, many improvements have been made in electrical amplification and in sound recording. Outdoor recording, though at first very crude, has gradually been refined. Sound photography in the open, as compared with ordinary soundproof studio recording, presents certain difficulties, and in addition, the recording of such unusually high sounds as those produced by birds requires specially adapted apparatus. Mr. Kellogg, under the direction of Professor True McLean, of the Cornell University Engineering School, and with the help of Mr. Arthur Stallman, has developed, in the past few years, special amplifiers and equipment to deal with these problems. The apparatus is mounted in a small Ford truck. Two hundred and fifty feet of microphone cable are used, and this gives the sound photographer quite a range. In addition, the microphone is mounted with a specially designed parabolic reflector, in such a manner that it is in the exact focus of the parabola. A gun-sight is attached to the outer rim of the parabola, and the whole device is mounted on a tripod; and is easily and noiselessly moved both in the horizontal and vertical plane. When a singing bird and the microphone are in perfect focus the sound of the bird is greatly amplified. This tends to cut out unwanted sounds, wind, etc., which are the bane of the outdoor sound recorder. With the aid of the parabolic reflector and the two hundred and fifty feet of cable, a good recording of a normally loud bird voice can be made at about 1,000 feet from the truck. Experience has shown that one can drive to within recording distance of most species of birds.



THE PARABOLIC REFLECTOR MOUNTED ON A TRIPOD

Bird sound is recorded best shortly after dawn. It is then that song is most persistent, and constant repetition of the song is necessary unless one is prepared to waste great amounts of film. The sound recorders arrive at location the night before the proposed recording.

The truck has a bunk, and the operator sleeps on location. He is ready to record at the crack of day. A second Ford truck is also used. This contains sleeping quarters for two men and carries the various cameras and camping equipment. A collapsible platform which is used in bird photography has been built for the roof of this truck. This platform can be raised about eight feet above the roof of the truck. The photographer can be, in many instances, on the same level with the nesting bird, and, if need be, a blind can be erected on the platform. In this way, the camera is often over twenty feet above the ground. When not in use the platform folds up and adds less than a foot to the clearance of the truck. It can be raised by two men in less than ten minutes, and has proved invaluable in securing intimate close-ups of the birds.

ALBERT R. BRAND
AMERICAN MUSEUM OF NATURAL HISTORY

FIRE-RESISTANT FABRIC FOR AIRCRAFT[1]

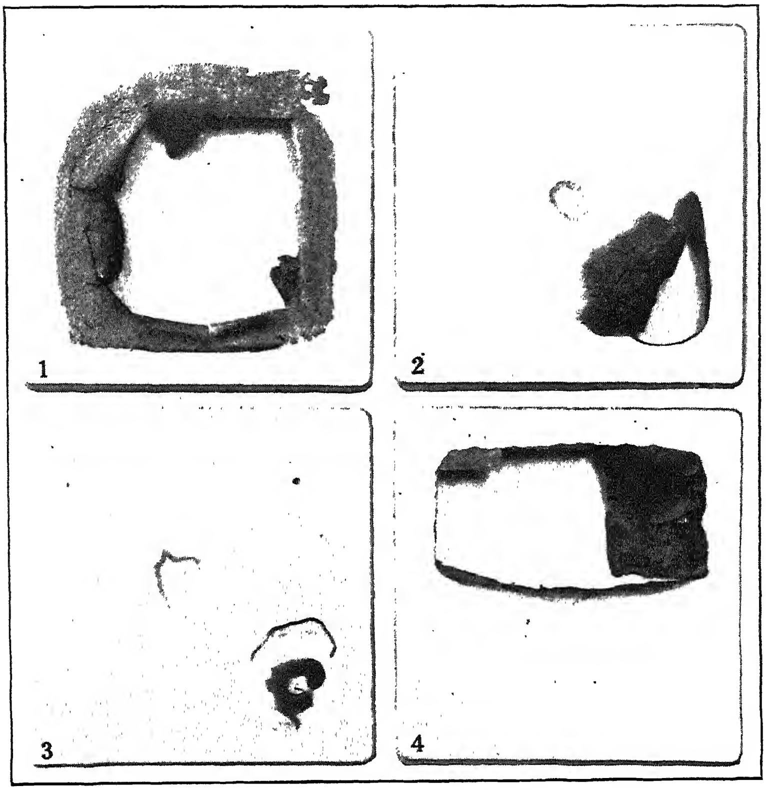
THE rapid growth of the aviation industry in this country has brought to the fore the problem of eliminating the fire hazard inherent in fabric doped with cellulose nitrate, now commonly used to cover the wings and fuselage of airplanes. The destruction of costly aircraft because of the accidental ignition of the flammable covering by the backfiring of the motor, the careless toss of a lighted match or cigarette or the chance settling of a spark from a nearby flue has become too general an occurrence. The rapid spread of flames following a minor crash presents a formidable obstacle to the rescue of trapped survivors. It has been stated that the use of metal will eliminate this hazard, but it is probable that, particularly for service airplanes, fabric will continue in use for some time to come because of its lower cost, availability and ease of application and repair, factors which facilitate rapid replacement of losses in time of war. An investigation was, therefore, undertaken by the National Bureau of Standards with the financial assistance of the National Advisory Committee for Aeronautics to develop a non-flammable doped fabric for aircraft.

A satisfactory airplane dope should tauten the fabric to which it is applied, dry relatively rapidly without "blushing," *i.e.*, precipitating the cellulose derivative in white patches because of moisture condensation, give a smooth, durable surface and permit a low film weight. To these we believe should be added the requirement that the doped fabric should be fire-resistant.

Natural and synthetic resins and mixtures of synthetic resins with cellulose nitrate and cellulose acetate were investigated. The resins did not tighten the fabric sufficiently to be satisfactory as airplane dopes. In general a 3:1 ratio of cellulose derivative to resin was necessary to attain satisfactory tautness. In this proportion even the least combustible resins did not markedly improve the fire-resistance of the doped fabric. No method was found to fireproof airplane fabric doped with cellulose nitrate and maintain satisfactory tautness and weight requirements. An airplane covering with excellent resistance to ignition was obtained by the application of a 3:7 boric acid-borax mixture to airplane cloth and subsequently doping it with cellulose acetate. This doped and fireproofed cloth, containing approximately 5 per cent. of the boric acid-borax mixture by weight, did not burn in a horizontal or vertical position and was not ignited by lighted matches or burning gasoline.

Although it is preferable to have a combination which is self-extinguishing,

[1] Publication approved by the director of the National Bureau of Standards of the U. S. Department of Commerce.



FLAMMABILITY TESTS ON DOPED FABRICS

1. UNTREATED AIRPLANE CLOTH DOPED WITH CELLULOSE NITRATE. 2. UNTREATED AIRPLANE CLOTH DOPED WITH CELLULOSE ACETATE. 3. FIREPROOFED AIRPLANE CLOTH DOPED WITH CELLULOSE ACETATE. 4. FIREROOFED AIRPLANE CLOTH DOPED WITH CELLULOSE NITRATE ON THE UPPER HALF OF THE PANEL AND WITH CELLULOSE ACETATE ON THE LOWER HALF.

such as can be obtained by fireproofing the airplane cloth before doping with cellulose acetate, if one is choosing between two materials which will support combustion, it is important to have the ignition temperature as high as possible. Various definitions and methods of measurement of ignition temperature have been proposed by investigators in this field, but there is general agreement that the ignition temperature of cellulose nitrate is approximately 200° C. below that of cellulose acetate. When it is considered that the temperature of ordinary incandescent lights, steam pipes and lighted cigarettes and matches exceeds the ignition temperature of cellulose nitrate, the constant risk of fire on an airplane covered with nitrate dope is readily apparent.

Published reports indicate that cellulose nitrate was considered undesirable for use at the "front" during the war, because of its flammability, and that cellulose acetate dope was preferred and, in general, prescribed for airplanes to be used in the zone of fire. Considering the comparative meagerness of the technological information concerning cellulose acetate in that period, its preferential use for doping airplanes is surprising and is indicative of the attitude of the wartime aeronautical engineers toward the fire hazard of cellulose

nitrate dope. After the war the development of cellulose nitrate lacquers received a remarkable impetus in the need of a low-cost, quick-drying coating material for many industrial purposes, notably automobile bodies, and rapid technical advances were made. New solvents were developed for cellulose nitrate, the common solvents were reduced in price by improvements in manufacturing methods and volume production, and the spraying process was perfected. As a result the improved cellulose nitrate lacquers, with a few changes to make them suitable for doping airplane cloth, gradually replaced the less hazardous cellulose acetate dope which was technically dead in that post-war period. To-day, however, the technical position of cellulose acetate has been altered. The rapid increase in the use of motion picture and x-ray films made from cellulose nitrate was accompanied by a number of serious conflagrations, which centered attention on the desirability of a relatively non-flammable film prepared from cellulose acetate. This acted as a stimulus to research on the production of cellulose acetate and its solvents, and resulted in a rapid growth of the manufacture of safety film and cellulose acetate plastics. Cellulose acetate dopes are, therefore, now only moderately more expensive than cellulose nitrate dopes. When it is considered that the cost of the dope is much less than 1 per cent. of the total cost of an airplane, this difference in price of the two dopes becomes insignificant as compared with the potential loss resulting from the destruction of the airplane by the accidental ignition of the fabric doped with the very flammable cellulose nitrate.

GORDON M. KLINE

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1935

BAMBOO—A TAXONOMIC PROBLEM AND AN ECONOMIC OPPORTUNITY

By Professor F. A. McCLURE
DEPARTMENT OF BIOLOGY, LINGNAN UNIVERSITY, CANTON, CHINA

Some Aspects of the Technique of Bamboo Study

During the course of my work in the field of economic botany at Lingnan University, I have naturally become much interested in the bamboos, a group of plants of great importance in the agricultural and industrial economy of the Orient. About fourteen years ago I began to collect herbarium specimens in southern China, a region very rich both in variety and abundance of bamboos. The plants collected were submitted to specialists for identification. The determinations returned for the bamboos were particularly inconsistent and unsatisfactory. My subsequent experience has made clear to me the chief reasons for these faulty determinations.

The fragmentary nature of the specimens, including types, existing in the herbaria of the world; the inadequacy of the original descriptions, frequently combined with failure to cite type specimens; and the confusion of names which prevails in most of the literature, are conditions which, while not peculiar to this group, are particularly accentuated in respect to the bamboos. Again, the average collector has only the vaguest idea as to what constitutes an adequate herbarium specimen of a bamboo. And, naturally, he seldom recognizes the need of supplementing his specimens with notes about those parts of the plant which he can not conveniently take with him, beyond recording the height and diameter of the stems. The nature of the underground part (the rhizome) and the branching habit, both characters of great diagnostic value, are usually either neglected entirely, or referred to only in the most general, or even inaccurate, terms. The making of adequate specimens of bamboos, even under ideal conditions, requires special knowledge and special techniques just as certainly as does the making of usable specimens of fleshy fungi, for example, or of certain groups of algae.

In defense of the average collector, however, it should be said that, of necessity, he usually makes his specimens of bamboos during the course of routine collecting. Also, many of the bamboos are exceedingly variable in respect to certain characters or structures. And, most important of all, several very essential structures of the bamboo plant are available only at more or less remote intervals. Moreover, it rarely happens that all the structures are available in good condition for collecting at any one time. The leaves are, of course, present throughout the year as a rule, but, in response to various factors, they range widely in respect to size and shape.

CUTTING A BAMBOO SHOOT

THE EDIBLE BAMBOO SHOOTS PRODUCED AT CANTON IN SOUTHERN CHINA COME CHIEFLY FROM SYMPODIAL BAMBOOS (*Bambusa* AND *Dendrocalamus spp.*). THESE SHOOTS ARE USUALLY CUT BEFORE THEY HAVE EMERGED FROM THE HEAP OF EARTH THAT IS THROWN UP AROUND THE BASE OF EACH CLUMP. AFTER THEY HAVE EMERGED THEY RAPIDLY BECOME FIBROUS AND DEVELOP A BITTER PRINCIPLE WHICH MAKES THEM LESS PALATABLE.

The culm sheaths are structures of great diagnostic value in most species, yet these and the prophylls of the culm branches are usually available in good condition for collecting during only a short portion of each year. The flowers are produced only after a long period of development, at least in most of the bamboos about which anything is known in this respect. When it is remembered that the organs of reproduction are the traditional basis of all taxonomic work with plants, the indispensability of these structures for purposes of identification is at once apparent. This holds notably for the grasses generally, and especially for the bamboos, where the vegetative bases for identification have not yet been established.

Considerable study has been devoted, especially in Japan, to the problem of the causes of the flowering among the bamboos, and it is quite possible that a way may eventually be found to induce the plants to produce flowers at will. It appears that flowering occurs more commonly in certain species during years of drought; the drainage of an area occupied by bamboo has been known to precipitate flowering in the whole grove, and injury by fire is often followed by flowering in some species. But until some reliable method has been devised which will enable us at will to cause recalcitrant species to flower without dying, we shall have to work along other lines.

Rarity of flowering among the bamboos presents, then, a real problem to the taxonomist. But there is another aspect of the behavior of bamboos which is scarcely less disconcerting, and that is the suppression of their vegetative activity during the flowering period. It has been my observation that when a bamboo plant comes fully into the flowering or reproductive condition there is always a very definite suppression of its vegetative activity. That is, when flowers are produced, there is a more or less complete cessation of growth in the leaf, stem and branches. This is just what we would expect to find, knowing what we do about physiology. But it goes to different extremes in different species. In some (the monocarpic[1] ones) the vegetative activity is reduced to such a low ebb that the whole plant dies. This is the story that one has heard many times in connection with some of the bamboos of India. In other species, however, only the portion above the ground dies, while the rhizomes remain alive and gradually give rise to new plants. Recovery is very slow, however,

[1] The term monocarpic means "producing fruit but once and dying after fructification." This condition is the rule among herbaceous annuals, but it is a rare condition among woody plants.

since all the foliage and the stored food used in the production of the inflorescences are lost to the living part of the plants. The new stems and new foliage produced by the rhizomes are often very much reduced in size at first, and the stem-sheaths are scarcely typical for the first year or two after flowering has ceased.

In still other species, and more commonly than is generally supposed, the flowering normally does not result in the death of any part of the plant, but is accompanied, nevertheless, by a more or less complete cessation of all vegetative growth over a period of variable duration.

From what has just been pointed out about the suppression of vegetative growth during flowering, it will be apparent that certain structures will be poorly, if at all, represented in specimens collected from plants in flower. This applies particularly to the culm sheaths and all other parts which are quickly destroyed by weathering. Sometimes even the leaves are almost entirely absent, especially during the advanced stages of flowering, or they may be much reduced in size. If, however, specimens are taken from plants not in flower, as is often done in order to get a fuller representation of the vegetative parts, they are almost useless to the taxonomist, with the knowledge of the group in its present state.

A question may be raised as to the feasibility of taking flowering specimens from one plant and vegetative specimens from another of the same species. This has been attempted in many instances, but the procedure is fraught with very grave dangers, especially when the vegetative structures of the species in question have not already been associated unmistakably with flowers of the same species. An instance came to my attention some time ago where, in the description of what was taken for a single species, characters from four distinct species belonging to two genera were mixed together. This would not be done wilfully, of course, but it may easily happen as a result of associating specimens from different plants on the assumption that they belong to the same species.

BAMBOO SHOOTS IN THE MARKET

In northern Kwangtung and northward the most conspicuous bamboo shoots on the market are those of the familiar *Phyllostachys edulis* (Carr.) Houz. Leh., a bamboo of the monopodial type. In winter the small, dormant shoots are dug up and marketed as a delicacy, but in the springtime these are sometimes allowed to reach a height of several feet and a weight of twenty pounds or more before they are cut.

My preliminary work on the bamboos has convinced me that familiarity with the living plants is an essential preparation for sound taxonomic work on this group. To achieve this, one must be able to return again and again to the same plants to make notes and take specimens at the different stages of their development, in order to assemble a sufficiently complete array of the structures essential for purposes of identifica-

tion. This conviction led me to undertake to bring together, at Lingnan University, living plants of as many of the Chinese bamboos as will grow there.

The Lingnan University bamboo garden was started in 1920. To date about 550 introductions have been made, mostly from seven provinces of China but including a few from the Philippines and from Indo-China.[2] Every introduction is given a distinctive number, the plants are tagged, and their position in the garden is plotted. A record is kept of the source of each plant, the date of its introduction, its vernacular names, its uses, if any, and any other observations which seem pertinent. When a plant is first introduced, herbarium specimens are made of all the available structures, and a record of these is kept, along with the information just mentioned. It very often happens that neither culm sheaths nor flowers are available at first. As soon as these structures appear, they are collected and the fact is recorded. Then, as the picture of the plant represented by each introduction number becomes more and more complete, its identity becomes clearer and clearer, the identity

BRINGING BAMBOO SHOOTS FROM THE COUNTRY

In April, over narrow, winding roads, farmers trek to town bearing baskets of succulent bamboo shoots.

[2] For plants of a number of species from Chekiang and Kiangsu provinces I am indebted to the Metropolitan Institute Museum at Nanking, through the coperation of the director, Dr. S. S. Chien, and Professor R. C. Ching, then botanist of that institution.

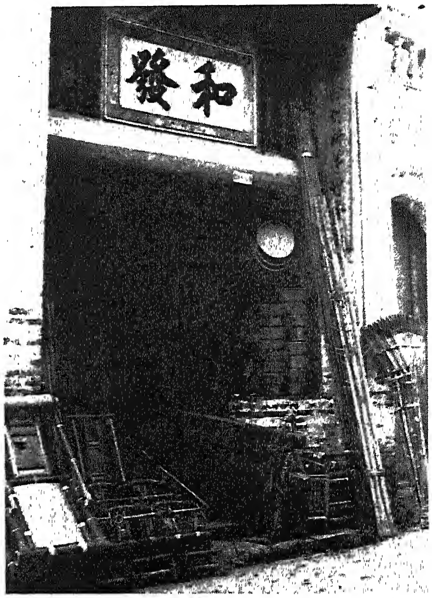
between different numbers becomes apparent, and finally, I have not only an adequate idea of the range of variation of each species, but I know its geographical distribution as well.

At first thought this seems like a long-time task. But one does not have to wait long for the results to begin coming in. Every year since the garden was started I have added numerous flowering specimens to the herbarium collection. Twenty-six of the plants were in a flowering condition when I left Canton in the summer of 1933. A subsequent report for last summer added another six numbers. A few have died in the act of flowering, while many have continued flowering over a period of years.

The central idea of this method, then, is to bring together a more complete picture of each species, embracing both the floral characters and the range of vegetative characters peculiar to each. Once accomplished, this will enable us to bridge the gap between any names which have been established in the literature on the basis of floral characters, on the one hand, and the plants as they grow, on the other. It will then be a relatively easy matter to identify bamboos in the vegetative state. Horticulturists have little difficulty in distinguishing the different kinds, once they are familiar with them. The difficulty is that no one is able, with certainty, to attach to many of them the correct scientific names. In the genus for which I have just finished a revision, I have had no trouble at all in finding good vegetative characters for distinguishing the species from each other.

Some Economic Aspects of Bamboo

The interest which bamboo has stimulated in the West grows largely out of the fact that this plant has, in many of its forms, played a very important part in the economic life of the people where it thrives, particularly in the Orient. Since very early times, no doubt, bamboo has supplied raw materials for food, clothing and shelter, as well as for many tools and utensils of everyday use. Even the essential writing materials, excepting ink, have been made of bamboo in China since the beginnings of historic times. Bamboo slips formed pages of the earliest books in China and, soon after the discovery of the art of making paper, bamboo became, and still remains,



A SHOP OF BAMBOO WARE
THIS DARK LITTLE SHOP IS FILLED TO OVERFLOWING WITH BAMBOO WARE OF EVERY DESCRIPTION—CHAIRS FOR YOUNG AND OLD, RICE BUCKETS, SIEVES AND TRAYS, CLOTHES POLES, RAKES.

so far as China is concerned, the paper pulp material *par excellence*. It is little wonder, then, that the civilization of the Orient has been spoken of as a bamboo civilization.

A list of the uses to which bamboos are put in the Orient to-day would be out of place here. One author recently published an incomplete list of some 200 such items. The compiling of such lists is a pursuit which has fascinated Western dwellers in the East since very early

THE PROTOTYPE OF OUR HOE DRILL IS FASHIONED FROM BAMBOO.

BAMBOO WATER WHEELS

IN EARLY SPRING SWOLLEN STREAMS ARE HARNESSED TO COMPLAINING BAMBOO WHEELS WHICH LIFT THEIR WATERS TO THE PADDY FIELDS.

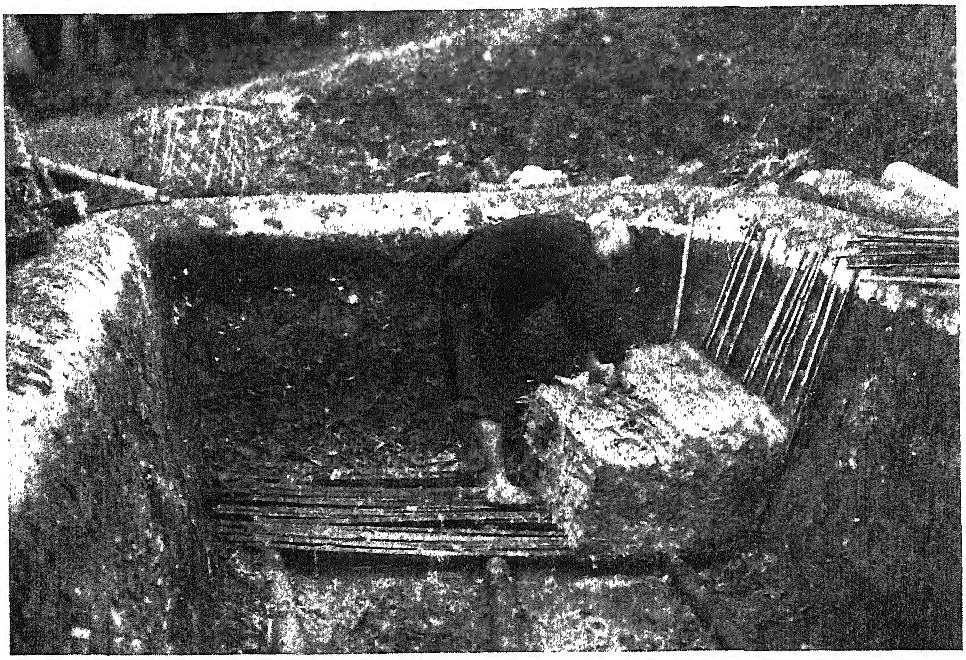
times. A far more interesting and significant aspect of the subject, and one to which I have seen very little reference in the literature, is that of the special adaptabilities of many kinds of bamboos to particular uses. Speaking of the bamboo economy of any given area, some articles are so regularly made of a particular kind of bamboo that one can only conclude that there are definite correlations between the structure and mechanical properties of the stems of the different kinds, on the one hand, and the requirements of the respective purposes for which they are used, on the other. In southern China, for instance, a certain species of bamboo, because of the stiffness and ruggedness of its stems, is always used for scaffolding and the frames of mat sheds. Another species, because of the evenness of its grain and the lack of prominence of its nodes, yields the entire supply of split bamboo which comes to this country for making certain types of brooms and brushes. Still another species, which combines evenness of grain and smoothness of nodes with unparalleled toughness and resiliency, is the only species now used to any extent in all the world for making split-bamboo fishing rods. Dr. Fairchild's article in a recent number of the *National Geographic Magazine* calls to mind an example from South America. Certain tribes of Indians there always make their blow guns, which are weapons of great accuracy, of a certain species of bamboo which is said to possess, among its distinctive characters, stems with one very long and very straight in-

WHERE BAMBOO ROPE IS MADE

BAMBOO ROPE OF VARIOUS KINDS IS WIDELY USED IN CHINA. THE TOWER HERE SHOWN IS USED FOR THE MAKING OF ONE SORT, WHICH IS BRAIDED FROM SLENDER STRIPS SPLIT FROM THE CULMS OF *Phyllostachys edulis*. IN THE VAT IN THE FOREGROUND, THE FINISHED PRODUCT IS BEING "CURED" IN LIME-WATER. THE LATTICED WALLS OF THE SHEDS AND THE PICKET FENCES ARE LIKEWISE MADE FROM SPLIT BAMBOO. TAKEN NEAR SHA-WU, KIANGSI.

ternode. Such examples could be multiplied indefinitely.

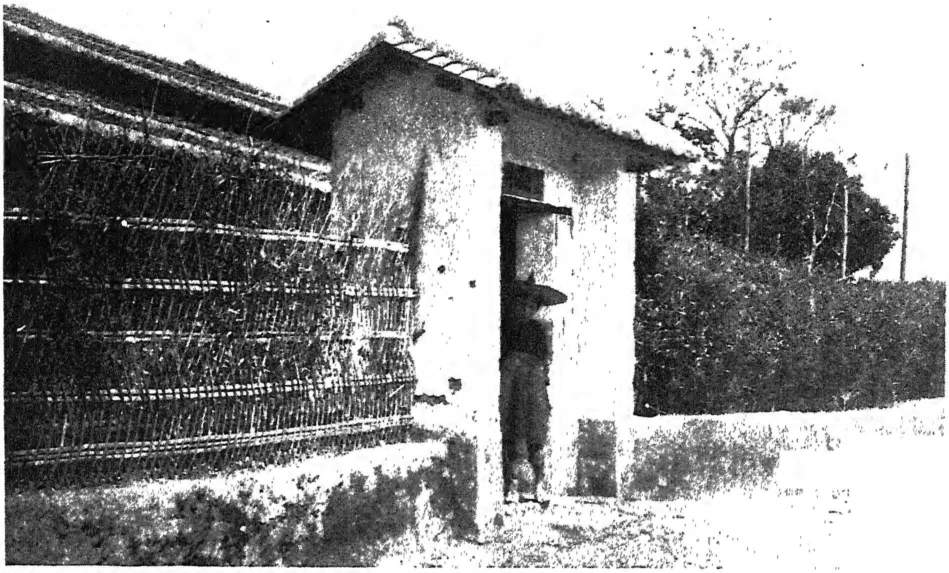
Speaking of bamboo in general, I will mention a few of the characteristics which give it certain advantages over similar materials, such as wood, rattan, etc. The physical properties of the stems, such as the hollow, cylindrical form, with diaphragms, make for relative lightness in proportion to strength. Its splitting qualities make for ease of working and economy of labor. The flexibility of slender strips of bamboo adapt it to the requirements of weaving and rope-making. The ease with which the stems may be warped by the use of heat contrasts bamboo favorably with other woods for many purposes. Finally, the natural stems lend themselves especially well to the making of various objects of rustic appeal. Then there is the ornamental value of the living plants, which makes them unique as horticultural subjects. The nutritive value of the young shoots, the forage value of the leaves, the high continuous productivity of bamboo per unit of land, once a plot is established, are points which suggest the promise of its winning eventually a place for itself among our economic cultures.



MAKING PAPER FROM BAMBOO

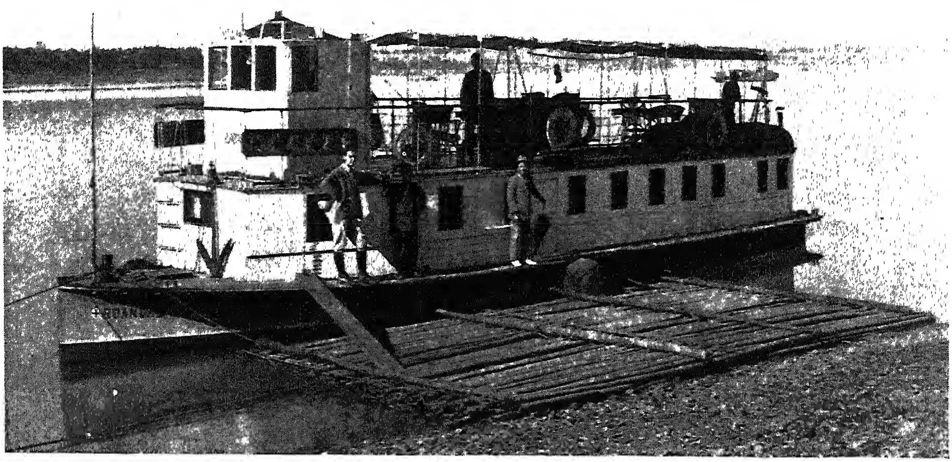
SOON AFTER THE DISCOVERY OF THE ART OF PAPERMAKING, BAMBOO BECAME, AND STILL REMAINS, SO FAR AS CHINA IS CONCERNED, THE PAPER PULP MATERIAL *par excellence*. THIS PICTURE SHOWS A RETTING VAT IN NORTHERN KWANGTUNG, FROM WHICH THE DIGESTED BAMBOO IS BEING REMOVED. THE MATERIAL IS NOW READY TO BE PULPED.

It will be necessary, however, to consider some of the potential obstacles to the rapid spread of the culture of bamboo in the United States. The unfamiliarity of our people with bamboo as a cultivated plant, with its cultural requirements and its potential usefulness in our scheme of things, must be overcome by gradual education. The present incompleteness of our knowledge concerning the kinds that will thrive in



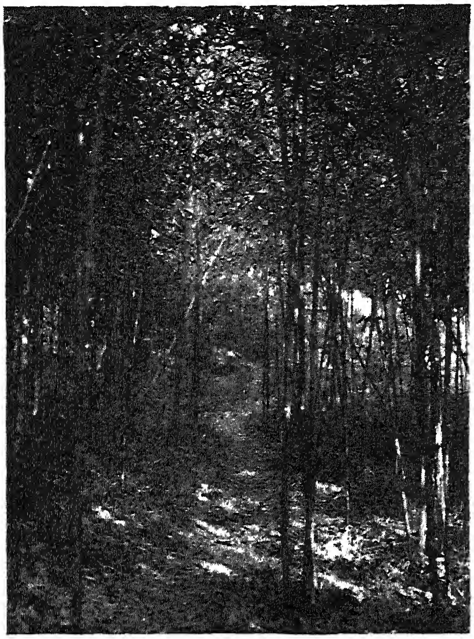
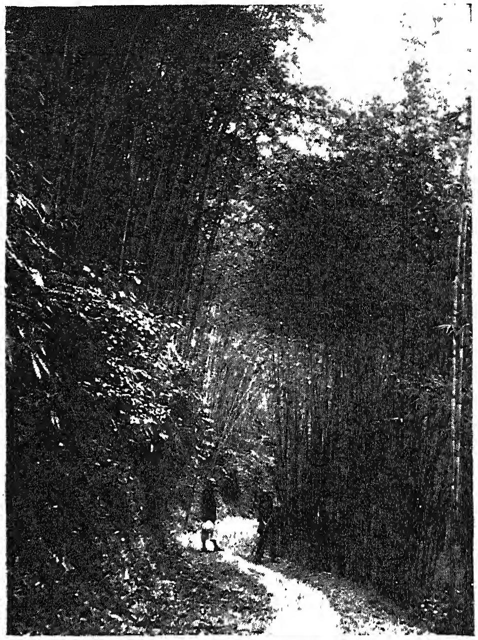
BAMBOO AS A GARDEN WALL

AS A LIVING HEDGE, OR A WOVEN LATTICE, BAMBOO SERVES EQUALLY WELL TO FENCE THE DOOR-YARD GARDEN OF THIS KWANGTUNG FARM.



AN INEXPENSIVE LANDING STAGE OF BAMBOO

WHICH FLOATS, SOLVES ADMIRABLY THE WHARF PROBLEM PRESENTED BY A RIVER WHICH HAS AN EXTREMELY VARIABLE LEVEL DURING THE RAINY MONTHS. WEST RIVER, KWANGSI.

FOOTPATHS WIND THROUGH GROVES OF BAMBOO

FLECKS OF SUNLIGHT, AND DELICATE SHADOWS PLAY UPON THE LEAF-STREWN FLOOR OF THIS INVITING GROVE ON THE LEFT. THERE ARE MANY SUCH GARDENS WITHIN THE WALLS OF THE CITY OF NANKING, WHERE THIS PICTURE WAS TAKEN. ON THE RIGHT, AN ANCIENT GRANITE PATHWAY WINDS ITS VARIED WAY THROUGH RUGGED BAMBOO COUNTRY.

this country and their possible cultural range, must be corrected by continued experimentation. A cheaper supply of plants for propagation must be made available. The amount of hand labor required for harvesting and preparing the stems may be overcome in part by the development of new techniques. The competition of a cheap supply of stems from the Orient will be operative for an indefinite period, but there are certain advantages in having a convenient local supply of fresh stems.

There are also a number of obstacles which will hinder the spread of the use of bamboo in the United States. Its use for structural and other purposes would involve disharmonies with our established habits. The units are not as easily standardized or modified as sawn lumber may be. Bamboo doesn't take nails. The wood tends to split too easily, especially under conditions of extreme atmospheric dryness. Most articles made from it will not stand the rough usage that we are accustomed to giving things. Greater labor and ingenuity are required to use bamboo than to use sawn lumber or other familiar structural materials, since unfamiliar kinds of tools are required. The durability of bamboo out of doors, and particularly in contact with the soil, is not high. It is also very susceptible to the attacks of wood-boring beetles, and is ruined thereby.

However, in spite of these obstacles, and almost without benefit of organized propaganda, bamboo has already made a considerable place for itself here in the West. It is now being widely used as an ornamental plant in gardens, for fishing rods, as handles for collecting nets, as

garden and flower stakes, for vaulting poles, parts of airplane wings, and phonograph needles. And very probably bamboo will soon be recognized here as a soil-binding plant to prevent erosion, as a forage plant on eroding areas and more widely as a food plant. There remains a wide variety of incidental uses it will find when more extensively cultivated. In the making of such things as ornamental lattices, arbors and rustic furniture, temporary fences, fruit-picking poles, sticks for cotton swabs, tongue depressors, home-made toys, toothpicks, etc., its possibilities are practically unlimited.

These simple uses alone would make a more general culture of the bamboos

THE GRAY BLOOM ON GREEN BAMBOO CULMS
ADDS AN INDESCRIBABLE BEAUTY TO THIS FOREST CATHEDRAL.

A CORNER OF THE LINGNAN UNIVERSITY BAMBOO GARDEN
AT CANTON, IN SOUTHERN CHINA.

worth while. But there is another point at which I believe bamboo is going to make a really dramatic entry into our economic life, and this is as a paper pulp material. The process of pulping bamboo has already been patented in all the leading countries of the world, and a large paper mill has been established at Foochow, China, which is said to be capable of pulping even the mature stems. We are now importing considerable quantities of wood pulp from Canada and Europe. And it remains to be seen whether we shall import bamboo pulp from the Orient, as soon as their supply exceeds their demand, or whether we shall make an attempt to produce bamboo on a scale sufficiently large to support a pulp industry here. Perhaps we may witness both of these developments within the next few decades.

In conclusion, I wish to make a brief reference to the esthetic appeal and fascination of the bamboo. The beauty of the stately culms, their graceful swaying at the touch of gentle breezes, the soft-textured verdure of the foliage, are a never-failing source of inspiration and delight to the artist and to the poet. Not only has the bamboo motif greatly enriched the artistic heritage of the world, particularly that of the Oriental peoples, but the plant itself has been taken by the Chinese people as a symbol of uprightness, chivalry and gentleness. We in the West would do well to give ourselves more fully to the esthetic, as well as to the economic, appeal of the bamboo.[3]

[3] Grateful acknowledgment is here made of my obligation to the Division of Plant Exploration and Introduction, Bureau of Plant Industry, U. S. Department of Agriculture, for permission to make use of photographs taken by me while acting as agricultural explorer in China.

EXILED ELEPHANTS OF THE CHANNEL ISLANDS, CALIFORNIA

By Dr. CHESTER STOCK

PROFESSOR OF PALEONTOLOGY, BALCH GRADUATE SCHOOL OF THE GEOLOGICAL SCIENCES, CALIFORNIA INSTITUTE OF TECHNOLOGY[1]

Introduction

Looking seaward from the strand at Santa Barbara, there may be discerned on a clear day one or more of the insular masses that skirt this portion of the coast-line of southern California. Extending from west to east the Santa Barbara or Channel Islands, as they are called, include San Miguel, Santa Rosa, Santa Cruz and Anacapa. The marine passages or channels which separate from each other the individual members of this group range in width from three to five miles and in depth from 17 to 110 fathoms. Between the islands and the mainland is the Santa Barbara channel which, opposite Santa Rosa, has a width of 29 miles and a maximum depth of 356 fathoms. In a southeasterly direction this channel becomes narrower and shallower. Opposite Anacapa its width is reduced to approximately 12 miles, while the depth here is for the most part less than 100 fathoms.

These islands rise from the submarine shelf and are now being gradually demolished by the ceaseless pounding of the Pacific, but agencies responsible for subaerial erosion are likewise assisting in the process of degradation. Considerable relief of the land surface is to be seen, particularly on Santa Cruz, the largest of the group, where elevations of 2,000 feet or more above sea-level are reached. The height of the land decreases on the islands lying westward of Santa Cruz and on Anacapa to the east.

Through the years much interest has been manifested in this insular group. In passing, mention may be made of only a few of the features that have served to attract students in historical and scientific research. The archeological materials which have been found there furnish an important record of the coast tribes of Indians of southern California. It is said that Cabrillo, the intrepid conquistador who discovered these aboriginals, is buried on San Miguel. To students of modern plants and animals and of their distribution in the Californian region, the flora and fauna of the Channel group offer much to engross attention. While there is no dearth of references to the geological features, the more general accounts and stray notes of earlier years have only recently given way to more detailed geological studies.

That the islands were once part of a peninsula, extending westward from what is now the mainland east of Anacapa, was advocated many years ago by Yates and more recently by Chaney and Mason.[2] An understanding of the geological history which this insular area has undergone is basic to a fuller appreciation of the biological features that characterize the region to-day. With notable changes in environmental conditions at least in part consequent to the partial subsidence of this ancient landmass, not only was the character and distribution of the life of the area affected, but the present peculiarities are likewise dependent upon the time when this occurred. Thus the islands present a fascinating biogeological study, in many respects comparable to that en-

[1] Contribution No. 162.

[2] R. W. Chaney and H. L. Mason, Carnegie Inst. Wash. Publ. 415, Art. I, 1930.

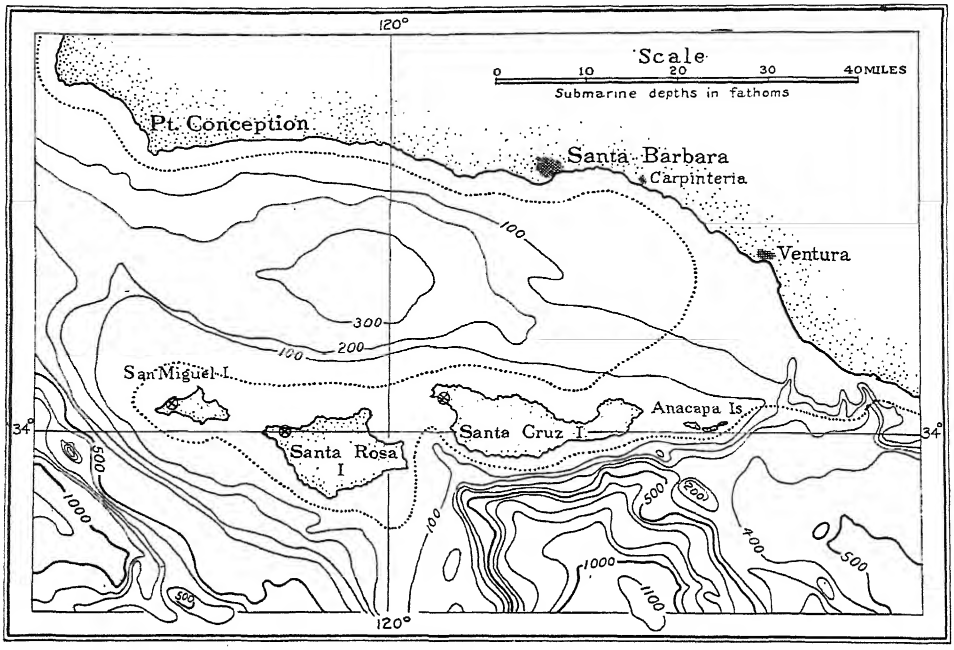


FIG. 1. MAP OF COASTAL PROVINCE OF SOUTHERN CALIFORNIA IN VICINITY OF SANTA BARBARA. LOCATION OF SOME OCCURRENCES OF FOSSIL ELEPHANTS ON CHANNEL ISLANDS SHOWN BY ×. DOTTED LINE INDICATES HYPOTHETICAL BORDER OF LAND DURING PLEISTOCENE TIME, AFTER CHANEY AND MASON.

countered on other continental islands of much larger size.

No more pertinent information indicating the lateness of the period of island formation can be furnished than that presented by a record of the former presence of elephants in this area. Aside from the importance of the occurrence of fossil mammals, however, the types themselves are of special interest because of their unique characteristics.

GEOLOGIC OCCURRENCE

Remains of extinct elephants are now known to occur on three of the Channel Islands, namely, on San Miguel, Santa Rosa and Santa Cruz (see Fig. 1). The first material was found on Santa Rosa more than sixty years ago, and this island has furnished by far the largest collection of fossil specimens representing these types. Similar material has been brought to light on San Miguel. In contrast to the rather numerous finds of elephant remains in Quaternary deposits of Santa Rosa, the presence of elephants on Santa Cruz is known thus far by only two fragmentary enamel plates of a cheek-tooth.

San Miguel: Although this island is wind-swept and shifting sand dunes mantle much of the area underlain by sediments of Tertiary and Quaternary age, the incision of the present land surface by ravines and gullies and the constant though gradual recession of the sea-cliffs develop exposures on which occasionally the weathered-out materials of fossil mammals have been discovered. Several tusks and cheek-teeth of elephants were found in a thin series of Quaternary alluvial deposits lying beneath a table-like surface and exposed in the sides of gullies near the northwest end of San Miguel. Scattered proboscidean teeth have been found from time

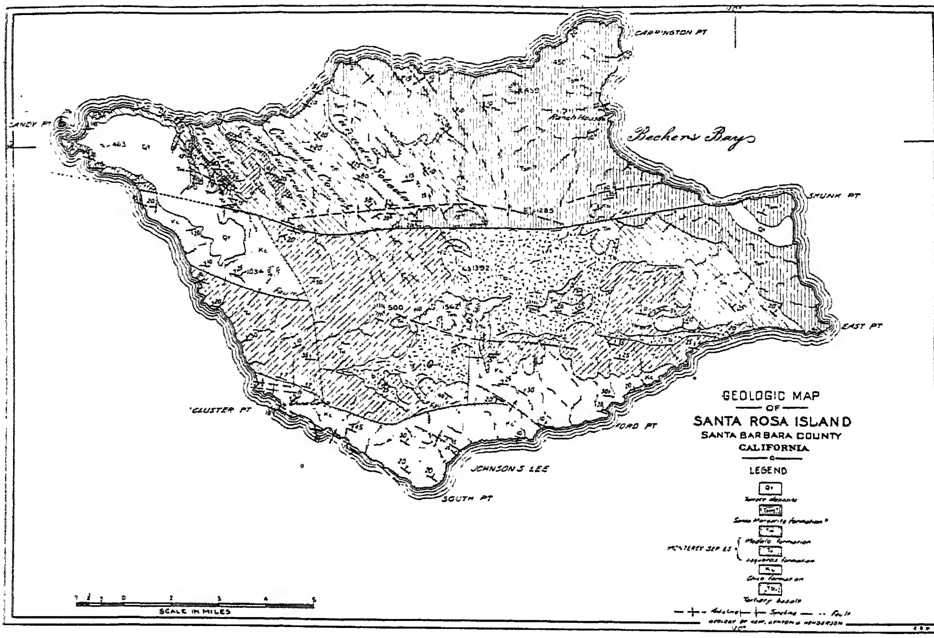


FIG. 2. GEOLOGIC MAP OF SANTA ROSA ISLAND; AFTER W. S. W. KEW. NOTE OCCURRENCE OF QUATERNARY BEDS AT NORTHWEST END OF ISLAND. DEPOSITS OF THIS AGE AND CONTAINING ELEPHANT REMAINS ARE NOW KNOWN TO EXTEND CONSIDERABLY FARTHER TO THE EAST.

to time elsewhere on this island. Among the fossil materials are specimens which clearly point to the fact that the San Miguel elephants are among the largest types to be obtained in the insular region.

Santa Rosa: Deposits containing remains of elephants occur at several localities, but the more significant discoveries of such materials have been made in Quaternary sediments forming a mantle over Tertiary rocks near the northwest end of this island (see Fig. 2). Excellent exposures of the fossil-bearing strata are extensively developed in the sea-cliffs and along the ravines or cañadas. Moreover, opportunity is afforded in this region to determine the relationship of these Quaternary deposits to the geologic events that transpired prior to and following their accumulation.

If we turn for a moment to the geologic events subsequent to the tilting of the Miocene marine sandstones and shales also exposed here, we note the clear evidence of at least three marine transgressions across these older rocks as well as several stages of uplift. The highest of the cut surfaces or marine terraces observed in this area has now an elevation of approximately 400 feet. The lowest cut surface, above the present strand, truncating the tilted Miocene rocks, has an elevation of approximately 10 feet. Between the two is another bench, bordered in front by a cliff which descends to the surface of the lowest terrace. The rear border of this intermediate bench is likewise formed by a cliff, whose position corresponds with that of the front of the upper terrace. The recorded diastrophic events and successive incursions of the sea are not unlike those which have been recognized on the mainland, along the Santa Monica coast and elsewhere. Resting on the lowest and intermediate benches are the Quaternary sediments which consist of gravels, sands or sandstones, coquina-

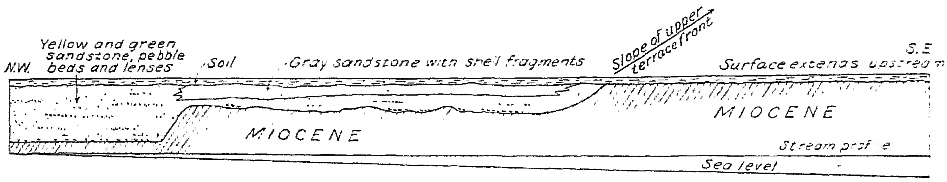


FIG. 3. GENERALIZED GEOLOGIC SECTION SHOWING RELATIONSHIPS OF THE QUATERNARY, ELEPHANT-BEARING BEDS TO THE UNDERLYING TERTIARY MARINE SEDIMENTS. NOTE THE LOWER AND INTERMEDIATE BENCHES (MARINE-CUT TERRACES) TRUNCATING THE TILTED MIOCENE ROCKS. DATA AND DIAGRAM FURNISHED BY F. D. BODE.

like deposits, and alluvial detritus. A generalized geologic section showing the relationships on the west fork of the Cañada Tecolote is given in Figure 3. Elephant remains are found in these deposits from near the base to within a short distance of the surface.

The Quaternary strata have a thickness of 40 feet or more and are capped by a remarkably even surface having an elevation of 75 feet or less above sea-level. This surface is well defined and parallels the coast for a considerable distance (Fig. 4). Unlike the upper terrace, the lower surface is not wave-cut but appears to have been formed as an aggraded surface by deposition of sediments in stream courses and in areas adjacent to the ocean strand after the streams, flowing from the more central portions of the land-mass to the sea, had become graded with respect to sea-level.

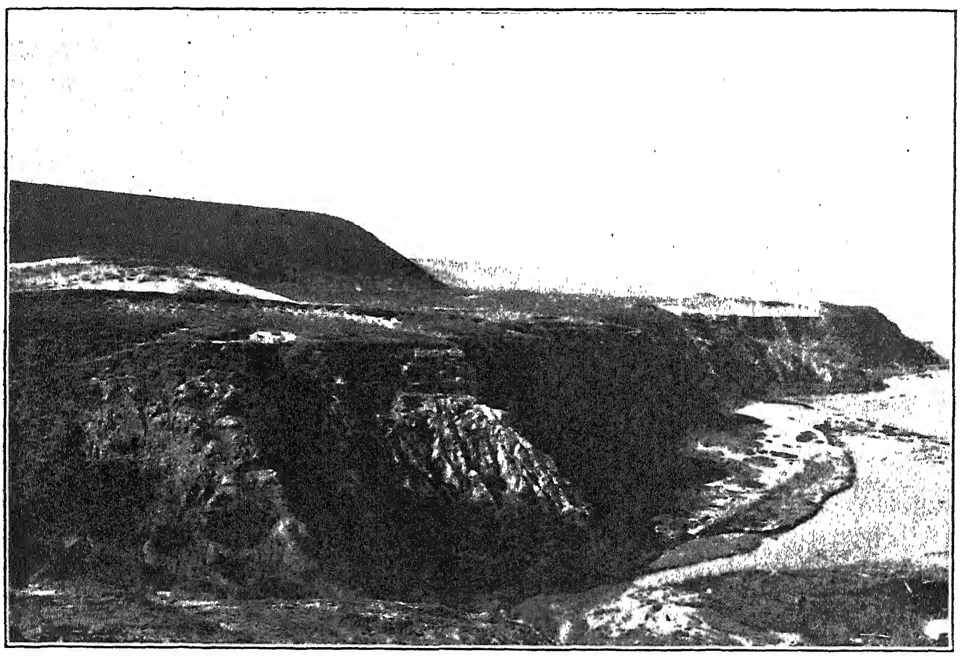


FIG. 4. VIEW LOOKING WEST ALONG NORTH FRONT OF SANTA ROSA ISLAND FROM ENTRANCE TO CAÑADA CORRAL

THE UPPER MARINE TERRACE AND THE LOWER SURFACE ARE CLEARLY SHOWN. EXTENSIVE EXPOSURES OF THE ELEPHANT-BEARING DEPOSITS MAY BE SEEN IN THE SEA-CLIFFS BELOW THE LATTER. SAN MIGUEL ISLAND SHOWN ON RIGHT HORIZON.

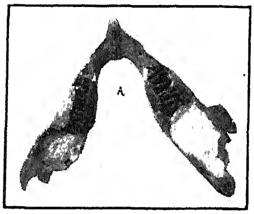
It is important to recognize, however, that since this has occurred, uplift of the land-mass has brought this surface to its present position and a new cycle of degradation and deposition has been initiated.

In the light of known information concerning the diastrophic history of the coastal province of southern California, it is reasonable to assume that the marine incursions and changes in elevation on Santa Rosa Island form part of a long and important series of geologic events featuring this province during glacial and postglacial time. Whether or not Pleistocene or Ice Age elephants had gained access to this portion of the ancient peninsula prior to the transgression of the sea, responsible for the cutting of the upper (400 foot) terrace, remains to be determined, but the advent of these creatures prior to that time may well have been the case. It appears probable that if the elephants had been present the period of their isolation occurred at that time. On the other hand, the length of time which has elapsed since mammoths were present in the region may be measured principally in terms of earth movements which have brought the elephant-bearing strata to their present position and in terms of erosion.

FIG. 5. EXCAVATING AN ELEPHANT TUSK
IN QUATERNARY DEPOSITS EXPOSED IN THE CAÑADA GALLION. SANTA ROSA ISLAND, CALIFORNIA.

At one locality at the base of the Quaternary strata occurred a whale vertebra and it may be presumed from this and from similar material found elsewhere that the cycle of deposition which brought about the accumulation of these sediments was initiated at least in some places under marine or estuarine conditions. The areal distribution of the Quaternary deposits and their abrupt termination along the present shore-line make it appear quite probable that the elephant-bearing beds extended originally for some distance northward, that is to say into the region now occupied

by the Santa Barbara channel. In the sequence of events that transpired during the period when elephants were living at this locality one may envisage a stage when shallow bays or arms of a large embayment fringed this section of the insular area, into which emptied streams that drained the hinterland. Under these conditions opportunities



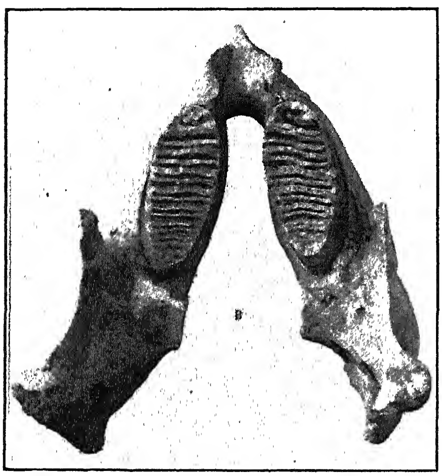


FIG. 6. *ARCHIDISKODON EXILIS* (STOCK AND FURLONG)
LOWER JAWS, VIEWED FROM ABOVE; *a*, FOETAL SPECIMEN, No. 172; *b*, PART OF TYPE SPECIMEN, No. 14, APPROX. × ⅛. CALIF. INST. TECH. COLL. QUATERNARY DEPOSITS, SANTA ROSA ISLAND, CALIFORNIA.

permitted an accumulation of sedimentary beds and an entombment of organic remains, similar to those which prevail to-day on a minor scale along this portion of the island coast.

Santa Cruz: Quaternary deposits occurring at the southwestern end of this island have been described recently by Chaney and Mason. These beds are particularly noteworthy because of a fossil plant record which they contain. Among the materials now known are logs of Douglas fir, representing a tree which in its native state is not known to range at the present time south of the coastal belt of northwestern California.

In the course of archeological field investigations conducted several years ago at the western end of Santa Cruz, two fragmentary enamel plates of an elephant tooth were found lying on an eroded surface of Quaternary deposits exposed along the ocean front, a mile or more away from the locality where the plant specimens occurred. A search conducted later for additional remains proved unsuccessful. In this area are a number of kitchen midden accumulations lying on Quaternary beds, and present erosion has washed and scattered some of the detritus from the middens over the older sediments. While the presence of tooth-fragments may well indicate the former existence of elephants on Santa Cruz, particularly in view of the occurrence of these animals on the more westerly situated islands, the possibility that the fragments were brought by the aboriginals to this island from Santa Rosa or San Miguel can not be wholly ignored. It is quite possible that such materials were seen and on occasion were picked up by the native inhabitants and may have been transported from one island to another with other articles of barter.

FOSSIL ELEPHANTS

It is clear from the occurrence of proboscidean remains on islands of the Channel Island group that elephants must have gained access to this region, prior to its present insular state, by way of some land-bridge or connection with the mainland. The alternate hypothesis, that mammoths reached the islands by crossing marine barriers more or less comparable to those that exist in the region to-day, can not be countenanced seriously in view of the formidable char-

acter of these barriers and in view also of the presumed habits of the extinct elephants as inferred from those of their living relatives. Frequent finds of fossil elephants made in Quaternary deposits of the Californian area clearly demonstrate that these mammals were well represented on the mainland and that they enjoyed a wide distribution over this western territory. Indeed, this may be said for much of the North American continental area during certain stages of the Ice Age. It is therefore quite permissible to assume that when the land in what is now the western end of the Santa Monica Mountains and contiguous area continued farther out to sea, elephants found no hindrance to an extension of range into this region.

It is important also to recognize that since the proboscideans, whose remains are found on the islands, had reached a stage of development in their evolutionary history characteristic of Quaternary time, their entrance into this land-area must have occurred during the geologic epoch immediately preceding the Recent. The length of time which elapsed during the Pleistocene or Ice Age is doubtless to be measured in terms of hundreds of thousands of years, but as yet the first appearance of elephants on that ancient land-mass can not be definitely fixed in Pleistocene chronology. As suggested under the discussion of occurrence, this event may have taken place prior to a time of considerable inundation of the land as represented perhaps by the stage of cutting of the terrace which now stands at an elevation of 400 feet or more above sea-level along the northern border of Santa Rosa Island.

At least two species of elephants, namely, the imperial and columbian mammoths, have been recognized in the fossil record of the mainland of California. As a matter of fact, these species are now included under separate genera,

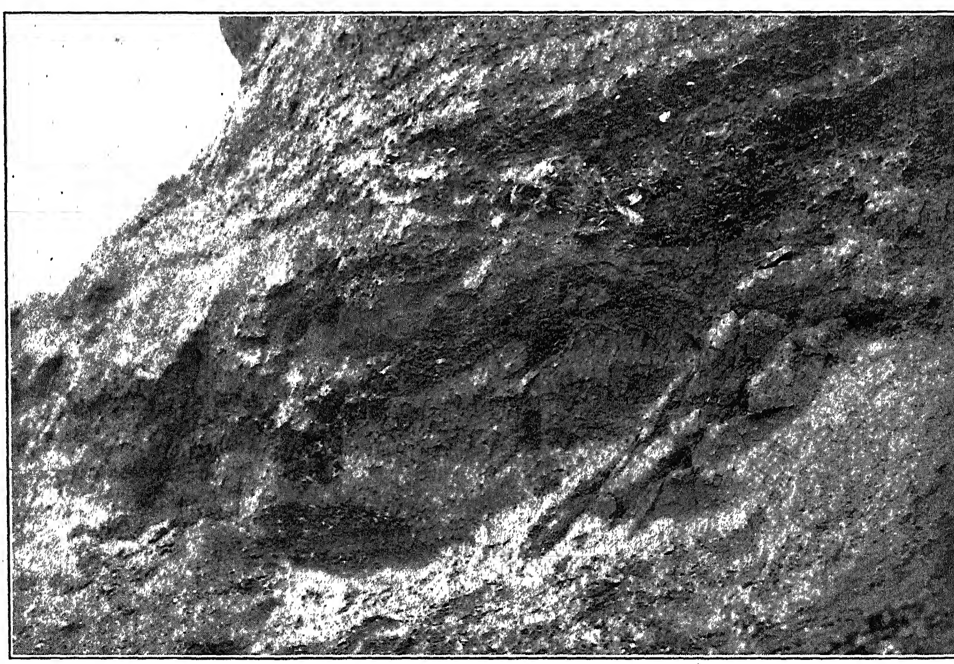


FIG. 7. SEA-CLIFF SECTION OF ELEPHANT-BEARING BEDS
NEAR MOUTH OF CAÑADA CORRAL SHOWING POSITION OF ELEPHANT SKULL BEFORE EXCAVATION.
SANTA ROSA ISLAND, CALIFORNIA.

Archidiskodon imperator and *Parelephas columbi*. When complete skulls and skeletons are lacking, specific identification of remains has been based upon recognition of structural characters in individual cheek-teeth. However satisfactory or unsatisfactory this may be, the island elephants show some resemblance in the characters of the cheek-teeth to the mainland types. In at least one particular, aside from the dental characters, they differ from the latter and in consequence were recognized by Stock and Furlong[3] as belonging to a distinct species, *Elephas* (*Archidiskodon*) *exilis*. Whether or not more than one species of elephant is present among the island forms remains to be definitely determined. In this connection, it should be recognized that an interesting and perhaps significant difference may exist between those forms on Santa Rosa and the types on San Miguel.

[3] C. Stock and E. L. Furlong, *Science*, n. s., 68: 140–141, 1928.

Numerous cheek-teeth and tusks, fragmentary jaws and skeletal elements comprise the bulk of the collections obtained on Santa Rosa. Individuals of all ages are preserved, from an unborn type to fully grown adults. The youngest specimen, evidently belonging to a foetus, is represented by a lower jaw (Fig. 6) in which the enamel plates had not firmly consolidated to form the lower cheek-teeth and had not erupted through the gums. One fairly complete skull represents an adult individual and furnishes valuable information as to the specific characters of the island elephants. When found in Quaternary strata, exposed in the sea-cliff near the mouth of the Cañada Corral, only the weathered cranial portion was visible (Fig. 7). Excavation revealed the rest of the skull and upper tusks (Fig. 8)

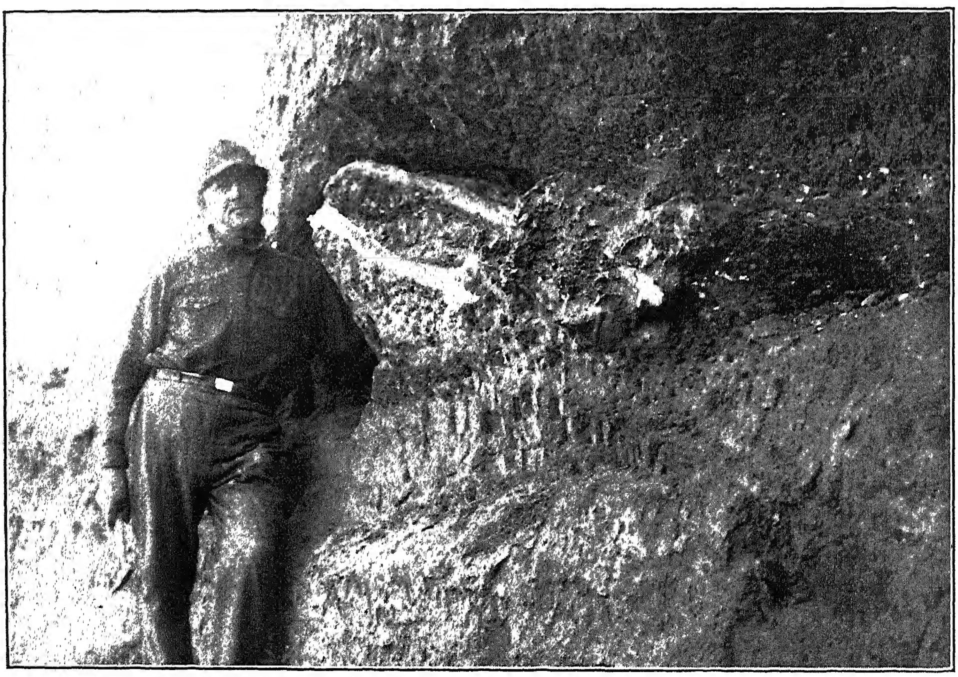


FIG. 8. SAME LOCALITY AS THAT SHOWN IN FIG. 7
EXCAVATION HAS EXPOSED SKULL AND TUSKS OF TYPE SPECIMEN OF *Archidiskodon exilis* (STOCK AND FURLONG). SANTA ROSA ISLAND, CALIFORNIA.

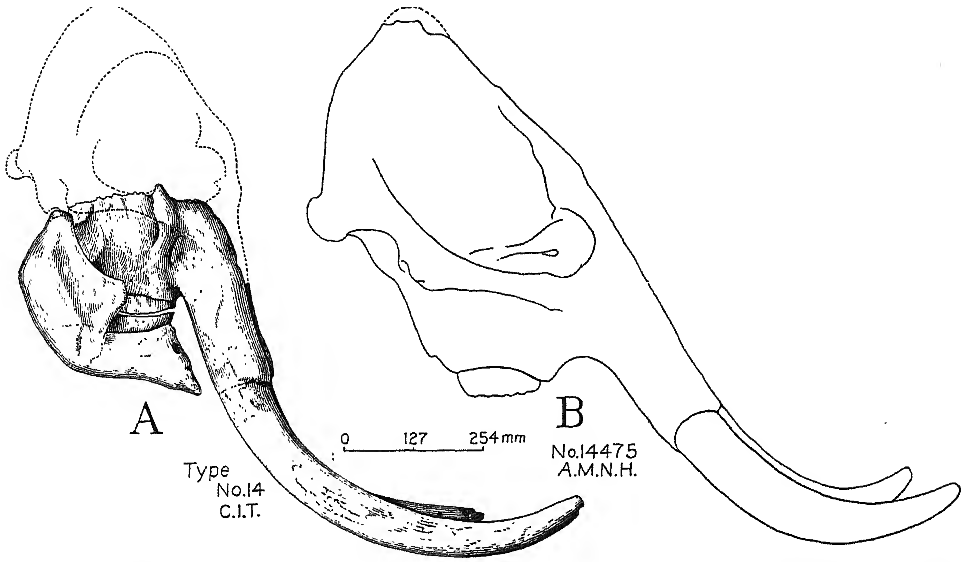


FIG. 9. COMPARATIVE VIEWS (TO SAME SCALE) OF (A) TYPE SPECIMEN OF *Archidiskodon exilis* (STOCK AND FURLONG) FROM THE QUATERNARY OF SANTA ROSA ISLAND, CALIFORNIA, AND (B) YOUNG ADULT OF *Archidiskodon imperator* (LEIDY) FROM THE PLEISTOCENE OF TEXAS. FIGURE 9B REVERSED, AFTER OSBORN.

with the lower jaw in position below the palate. Illustrations of this specimen and of a young adult skull of the imperial mammoth (*Archidiskodon imperator*), drawn to the same scale, are shown in Figure 9.

Comparison of fossil remains of elephants found on Santa Rosa with comparable materials occurring on the mainland establishes clearly the fact that the island forms were smaller in stature than their relatives of the mainland. Considerable variation in size exists among the island types, but the difference in stature between island and mainland forms remains a notable feature. This difference is apparent in Figure 9 and is strikingly demonstrated likewise in a comparison of limb elements (see Fig. 10). While the elephants of the mainland ranged in height from approximately 10½ feet to 13½ feet as measured at the shoulders, those of the islands presumably never exceeded 8 or 9 feet in height and the smaller individuals were probably no taller than 6 feet. Thus, the smaller size of these elephants presents a character wherein they resemble the fossil or subfossil, dwarfed elephants described from the Maltese Islands of the Mediterranean. The diminution in size, however, has not been carried so far in the Channel Island elephants as in the Maltese species.

When an attempt is made to account r this distinguishing feature among the island types, two alternatives present themselves. Either the elephants that originally penetrated this ancient land-area were a race of small individuals, or the mammoths now found fossil on the islands exhibit a smaller size, in contrast to mainland forms, as a direct or indirect result of their insular isolation. As yet, no information is at hand to indicate that a species of elephant with the characters of the island forms was in existence during Quaternary time along the littoral of the southern California mainland.

On the other hand, when the difference between the island and mainland

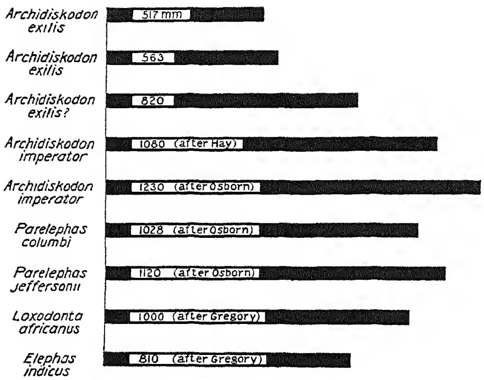


FIG. 10. DIAGRAM SHOWING COMPARATIVE LENGTHS OF HUMERUS IN PLEISTOCENE AND RECENT ELEPHANTS. THE NUMBERS REFER TO THE LENGTHS OF THE HUMERUS IN MILLIMETERS. NOTE THE SHORTNESS OF THE BONE IN THE ISLAND SPECIES, *Archidiskodon exilis* (STOCK AND FURLONG).

forms is coupled with the fact that oscillations of the land occurred in late geologic time in the region now occupied by the Channel Islands, one may be led to assume that restricted terrain, limited environmental conditions and food-supply and inbreeding have been influential in establishing the specific characters possessed by the island elephants. Certain it is that these conditions, and perhaps others, would arise, were island isolation the final stage in the history of a group of mammals whose former range extended over a much larger and continuous land-area.

As mentioned before, the elephants of San Miguel are among the largest types to be recorded from the island region. Tusks of these forms have been found which measure 5 feet in length and 6 inches in diameter at the base. While some of the fossil materials on Santa Rosa likewise indicate the former presence of relatively large individuals, it is possible that the average size of the San Miguel elephants was larger than that of the Santa Rosa types. Were this ultimately established to be the case, on the basis of a comparison with more extensive collections than are now available from San Miguel, it is interesting to speculate whether the difference may not have been the result of an earlier extinction of elephants on the smaller of the two islands.

CONCLUSIONS

The occurrence of extinct elephant remains in deposits of Quaternary age on islands of the Channel Island group points to the former presence of a land-connection between the insular area and the mainland. The fact that these proboscideans were in a Quaternary stage of evolution when they lived on the ancient land-mass emphasizes the relative recency of the geologic events that brought about the insular conditions.

No small elephants with the characters of those found on the islands have been recognized thus far in Quaternary deposits of the mainland of California. It is fair to suppose, especially in the light of the later geologic history of the island area, that the characteristic size of the island elephants results from insular isolation. Further, the difference in stature between island and mainland forms may be an index of the length of time which elapsed during the period of exile.

MARRIAGE AND SEX CUSTOMS OF THE WESTERN ESKIMOS

By CLARK M. GARBER

FORMERLY PROFESSOR OF BIOLOGICAL SCIENCES AT CAPITAL UNIVERSITY AND SUPERINTENDENT OF ESKIMO AND INDIAN SCHOOLS IN ALASKA FOR THE UNITED STATES BUREAU OF EDUCATION

An intelligent discussion of the marriage and sex customs and practises of a primitive people presupposes the author to have lived with them for a comparatively long period and to have made a systematic and organized study of their culture. One is not given the opportunity to study the intimate life habits and customs of a people by brief contacts with them. A perspicuous knowledge of the Eskimos' private life can be acquired only by living intimately with them, and particularly through the enjoyment of their utmost confidence. The scientist or student who would learn the things which lie within the secret lives of the Eskimos must be prepared to isolate himself from the civilized world, and for a period of time virtually become an Eskimo in his life habits. A few scientists and students—Nelson, Petrof, Rassmussen, Jenness, Stefansson, etc.—have been willing to suffer such isolation and hardships in order that they might contribute accurate information to the world's knowledge of Eskimo culture, while others have been content with cursory investigations. The cursory investigation can lead only to distorted ideas, exaggerations and false information. Unfortunately, much of this misinformation finds its way into print for the reading public to consume, and thereby false conceptions concerning the Eskimo people are broadcast.

The short-time investigator is unknowingly apt to find the Eskimos prepared to give him just the information he wants. They readily sense what is desired and often purposely deceive those who would learn their secrets. Furthermore, the Eskimo is prone to put only his good side forward. In his legends of conflict with the white man his side is always superior in arms, skill, strategy and shrewdness. His answers to interrogators are made to fit as near as possible to his interpretation of the white man's ethics. But there can be no doubt that a conscientious and intensive study of the Eskimo in his living state will yield a more lucid conception of his culture than will be gained by a lifetime study of museum specimens, especially when such study is the result of a comparatively long and intimate life with them. A picture of the Eskimos' past culture may be drawn from archeological specimens taken from reputed ancient village sites, and may also be drawn from their present culture and folk-tales handed down through innumerable generations. But if our store of knowledge of Eskimo life, past and present, is to approach a reasonable degree of accuracy it must be built upon an exhaustive study of both these sources of information.

The customs and traditions of a primitive people vary according to locality, clan, tribe, village or dialect, and thus we find it among the western Eskimos. This variation is not as distinct to-day as it was prior to their contact with the white man. Demarcation lines between tribes or clans have melted away, because of the white man's efforts to Americanize the Eskimos. It is therefore very difficult to determine where the Innuits, Kuskokwagamutes, Nunivagamutes, Malmutes or Unalits begin or end, and unless the investigator is familiar with Eskimo philology he may

find himself at a loss to differentiate them.

The Inception of Sex Knowledge

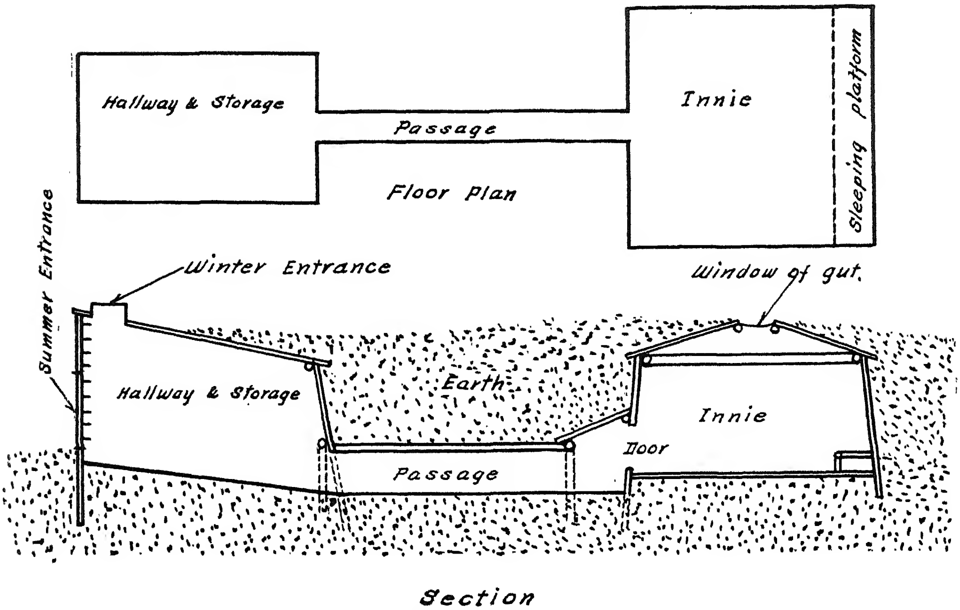
To the reader it may be an astounding fact that the Eskimo children learn of sex matters as soon as they are able to form ideas. To them it is not a matter of parental teaching in any form. It is a matter of observation, because they witness family functions being conducted right before their eyes. There is no effort on the part of the parents to conceal such matters from the children. The Eskimos' permanent home is an underground structure called an Innie.[1] The floor area of the actual living quarters does not average more than two hundred square feet. In this small room may often be found living a father and mother, three to six children, possibly an older son or daughter who is married, and likely the grandparents. Under such crowded conditions in such a small place the children, from the youngest up, witness the performance of all family functions. By their nature Eskimo children are great imitators. They attempt to mimic everything they see done. Hence their early and natural attempt at participation in sex relations, particularly during their play at housekeeping. I have witnessed Eskimo children at play during which the mimicry of the sex act of their parents was just as important a part as the sewing, tanning, caring for the imaginary children, etc. The dolls of the Eskimo children are in most cases fashioned in the form of the complete nude of either sex, *i.e.*, they are not asexual. At the age of ten to twelve years the Eskimo boys and girls arrive at puberty. No sooner is this in evidence than the parents are anxious to marry them off so that they may enjoy further means of support during their declining years. This is particularly true of the girls, since they do not contribute to the support of the family. Among the Innuits it was not uncommon to mark a girl by tattoo lines as an indication that she had attained the marriageable age. In the region of the Yukon and Kuskokwim Rivers Delta the girl's father would pass the news among the young hunters that his daughter had arrived at her first catamenia and could therefore be married any time. In this same section I found several instances in which the girl's mother, by physical manipulation, prepared her small daughter for the process of copulation in order that complete satisfaction might be assured the prospective husband, who was a skilled young hunter having the marks of an excellent provider. However, mating does not always take place immediately after puberty. It is often postponed until much later, and I have known both girls and boys to be between twenty-five and thirty years old before they were permanently married.

In the translation and compiling of a volume of folk-tales of the western Eskimos[2] I have found a large per cent. of their stories and legends based upon sex, mating, propagation and birth. These stories are often told to children as bedtime stories; hence they early in life become sex-minded. For instance, in their stories, "The Daughter of a Witch Doctor" and "How the Yutes first came to Nuviakamute," direct and literal reference is made to cohabitation, childbirth and sexual indulgences. In their folk-tales they talk about sex exploits as familiarly as we tell our children about Red Riding Hood.

Child betrothals among the western Eskimos are not uncommon, although it has never developed into a general practise or custom. Usually such betrothals take place between parents who are particularly affluent, and wish their good

[1] *Innie:* The permanent home of the western Eskimos built under ground.

[2] "Folk Tales of the Western Eskimos," by Clark M. Garber. Not yet published.



FLOOR PLAN AND SECTION OF A BERING STRAIT TYPE INNIE

IN ANOTHER TYPE OF INNIE FREQUENTLY CONSTRUCTED BY THE WESTERN ESKIMOS THE DOOR TO THE INNER CHAMBER CONSISTED IN AN OPENING IN THE CENTER OF THE FLOOR. THIS OPENING WAS CONNECTED BY A DEEPER TUNNEL RUNNING DIRECTLY UNDER THE INNIE FROM THE HALLWAY.

fortune to continue with their children. Or the parents of the betrothed children may be especially good friends and desire to honor each other through the betrothal and subsequent marriage of their children. In the case of a child betrothal the actual marriage does not take place until the girl and boy have reached the age of puberty or later. In the meantime they are not permitted any sexual freedom between them, but each may have such indulgences with others. Nelson says,[3] "From the lower Yukon to the Kuskokwim child betrothals are common and may occur in two ways. In such cases the girl is frequently not over four or five years old. Sometimes such arrangements are made by a couple to take effect when the first girl is born. In these child marriages when the girl reaches puberty both she and her husband are considered unclean, and neither of them is permitted to take part in any work for a month, at the end of which period the young husband takes presents to the kashim and distributes them. After this he enjoys the rights of other heads of families."

PROMISCUITY

The freedom of sex relations among the western Eskimos and particularly among their unmarried youth can not, by any reason or theory, be laid at the door of licentiousness. Such freedom of sex can be interpreted only as a biological development which has for its purpose the propagation and perpetuation of the race. I regret to say that the lewd side of Eskimo life developed as a result of their contacts with the white man. Murdock says of the Point Barrow Eskimos,[4] "promiscuous sexual intercourse between married and unmar-

[3] Nelson, Eighteenth Annual Report, Bureau of American Ethnology, pp. 291, 292.

[4] Murdock, Annual Report, Bureau of American Ethnology, No. 9, p. 419.

ried people, or even among children, appears to be looked upon simply as a matter for amusement." With due deference to Mr. Murdock's investigations, I fear that he was somewhat deceived by appearances. The amusement side of sexual freedom among the western Eskimos did not develop until they learned from unscrupulous whites about the sensuous pleasures they might derive from the abuse of a natural process which, up to that time, functioned in a natural way. Of course we can not believe that the Eskimo, even in his most primitive state, is ignorant of sex gratification. That would be both unreasonable and unnatural, but the conversion of their natural sex relations to a state of licentiousness was inaugurated by foreign influence. We learn by life in an Eskimo colony that the abuse of the practise of sex freedom was frowned upon. Farther on in his report, in his criticism of Mr. Simpson's writing, Mr. Murdock says,[5] "since the immorality of these people among themselves, as we witnessed it, seems too purely animal and natural to be of recent growth or the result of foreign influence." The proper interpretation of this statement hinges on the word immorality in the sense in which Mr. Murdock applies it to the practise of sex freedom. After many years of intimate life with the western Eskimos it is impossible for me to interpret their sexual freedom in any sense of moral turpitude, because it is purely biogolical. It is fairly certain that they would not talk to their children in unrestrained terms regarding sex matters if they knew it to be contrary to custom and tradition. It is around custom and tradition that their sense of right and wrong is built. What appeared to Mr. Murdock to be amusement in connection with their sexual freedom was naught but their amusement at the white man's inquisitiveness.

[5] Murdock, Ninth Annual Report, Bureau of American Ethnology, p. 420.

The birth of a child out of wedlock is considered very improper, and usually means a severe scolding from the parents. But a girl who has given birth prenuptially is by no means disbarred as a candidate for marriage. In fact, her fecundity is thereby proven, and since children represent the criterion of a happy marriage she has no particular difficulty in finding a husband. It is in reality a greater crime for a girl to be barren than to have children out of wedlock. A girl who is barren is wanted by no man. She may become the second or third wife of a man, but because of her inability to bear children she will have all the menial tasks about the household to perform. In a later paragraph—"Influence of the Whites"—it will be found that prenuptial childbirth is often favored, especially when the father is a white man.

Promiscuous sexual intercourse among the youth of a primitive Eskimo village seldom, if ever, becomes a licentious matter to the extent of producing prostitutes. Prostitution found among the Eskimo girls is not a natural result of sex freedom. It is the result of the white man's perfidy. In all their legends, stories and folk-tales we find not a single reference to any condition or situation which might be interpreted as prostitution. Widows are more apt to become prostitutes than unmarried women. A widow who has already borne a family often becomes the common property of the men of the colony. The young men prefer her services to the services of the young girls. This apparent prostitution does not bar the widow from subsequent marriage, and when such marriage does occur she again becomes chaste. Any children she may have borne during her widowhood as a result of her prostitution are given away to childless couples, who are highly pleased to get them. In my inquiries into such cases of prostitution I have found that the widow does not so behave

of her own choice. Custom and tradition wield a powerful influence in the matter, so that she is more often forced into prostitution against her desire than by her desire.

Marriage Customs and Ceremonies

The primitive Eskimo has never developed a complex ceremony by which husband and wife are bound in wedlock. His mating is almost as simple as the mating of wild animals. His marriage is based on the economics of his existence. In the first place a wife who is a good housekeeper, skilled in making of fur garments and footwear, and efficient in the butchering and preparation of meats and skins, is most desirable. But the predominant factor in Eskimo mating is the wife's ability and willingness to bear children. Every young hunter in contemplating marriage considers this factor first. This is partly due to nature's scheme for propagation and perpetuation of the race, and partly due to tradition and custom. The result is a probationary marriage. The young hunter looks upon all the likely girls in the colony and observes them at their daily tasks. When he has decided upon the girl whom he believes will make him a good wife he approaches her father or guardian to arrange the matter. The prospective father-in-law, who is usually glad to be rid of his daughters, may agree to the young man's proposal, but exacts from him a promise to hunt and fish and turn the proceeds over as his consideration in the agreement. This, however, does not consummate the marriage relation. In the Yukon and Kuskokwim Delta region the young hunter takes the girl to his camp and lives with her in a state of trial marriage for a year. If children are begotten, proving the girl's fecundity, the marriage is thereby consummated. But if the girl fail to become pregnant with child she is returned to her parents, and the young hunter is free to select another. In the Bering Strait region and on St. Lawrence Island the period of probationary marriage may endure for three years, during which time the girl remains with her parents and the young hunter must turn over his entire catch to his prospective father-in-law. Co-

Photo by A. B. Martin

A TYPICAL ESKIMO WOMAN
of the Kuskokwim River Delta region. The ornaments worn across the breast of the parka are two brass alarm clock wheels, and between them a Russian bell. Approximate age 22 years.

habitation of the young hunter and his trial wife is permitted during this period, and if the relation does not prove satisfactory it may, without ceremony, be broken by either party. In such cases the trial husband is the loser, because he will have hunted and fished for the girl's

parents and receives no return for his efforts. The probationary marriage and the return of the trial bride to her parents in no way affects her chances for a successful marriage, for she may soon be chosen by another hunter, and this time prove her desirability by bearing children.

In the region of Bering Strait and the Arctic Coast the girl's consent is necessary before a trial marriage may be arranged. The young hunter in all cases must have merited the title of hunter by delivering his first kill of each kind of animal to the oldest man or chief of the village, who divides it into as many parts as there are innies in the village. Each home group receives a portion while the young hunter receives some undesirable part of the animal or none at all. Once he has qualified in this manner, he is accepted by the hunters of the village as one of them, and is then in a position to marry. When arrangements for the trial marriage have been concluded with the prospective father-in-law the young hunter retires to the cosgy,[6] where he awaits acceptance or rejection by the girl he has chosen. If within due time she brings into the cosgy and sets before him a platter of choicest foods she thereby indicates her acceptance. Grasping the wrist of the young man she guides his hand to and from the platter while he eats with as much gusto as will indicate the degree of his pleasure. Thereafter the young hunter takes his trial wife to his isolated hunting camp or, as frequently happens, he goes to live with the girl in her parents' innie. If within the period of probationary marriage a child should be born to them the marriage is thereby consummated. If no children are born to them the husband is free to return the girl to her parents and select another. The length of the probationary period is controlled by the shortage or plentifulness of girls in the colony. If a shortage of females prevails a father may exact a greater price for his daughter, and if there are plenty of females there is less competition, which results in a much shorter trial marriage, and less service on the part of the young husband.

[6] *Cosgy*—The village meeting place built on the order of a very large innie.

Courtship

It will be seen in the foregoing paragraphs that courtship and love-making take place during the probationary marriage period. The western Eskimo, although capable of affection, is undemonstrative. There can be no doubt that a successful marriage promulgates a sense of love and affection between mates, but there is no marked development of this relation prior to marriage. Mr. Hall bears out this statement in his assertion,[7] "Love—if it comes at all—comes after the marriage." The folktales of the western Eskimos bring to light very little regarding love matches, but do deal very frequently with marriage arrangements, freak marriages and pertinent ceremonies. In the case of the Eskimos of the Bering Strait region it is apparent that a sort of courtship exists when the chosen girl carries food to and feeds her promised husband in the cosgy. This is usually accompanied by a considerable demonstration on the part of the male, just as a peacock struts before his mate. Undoubtedly it is accompanied by, or more likely caused by, an impelling sex impulse which might be termed courtship. Throughout their legends and stories there comes to light the functioning of the instinct to show off before the opposite sex, and the same instinct functions in their lives to-day. This does not lead to open courtship or love-making, but it does have a definite bearing on the matter of the young

[7] Hall, "Arctic Researches," p. 568.

hunter's winning the girl he wants. If two men should select the same girl at the same time there must follow a series of contests in which the winner takes the girl and the vanquished seeks another. Furthermore, courtship of a girl almost always includes the courtship of her parents' favor. To accomplish this, the young hunter endeavors to perform some outstanding act of valor, some singular success in hunting or some difficult feat of endurance. In their legend[8] "How Quakseetko Won a Wife," from the Bering Strait Eskimos, we discover a vivid portrayal of the type of courtship, which was no doubt the usual procedure. Among the Eskimo girls and boys of lesser prominence the process followed the same general form, but was much less romantic.

Influence of the Whites

In those parts of Alaska where the whites have contacted the Eskimos for a comparatively long period the blood of the Eskimos has been so thoroughly mixed with the blood of the white race that one would have great difficulty in identifying a full-blood Eskimo. By reason of their practise of sexual freedom the Eskimo girls are exceptionally gullible to the advances of unscrupulous white men. Furthermore, they have quickly recognized the marked improvement in the mental and physical characteristics of their offspring when they cross their own blood with that of the white man. Except in the primitive Eskimo villages this mixing of bloods has taken place to such an extent that the Eskimo girls now consider it an honor and something very desirable to bear a child by a white man, and it matters not whether in wedlock or out. I have in mind three specific cases in which the desire to bear children by white men became so impelling that the Eskimo girls deliberately requested cohabitation. In one of these cases the refusal

A YOUNG ESKIMO WOMAN
OF THE BERING STRAIT REGION. THE BERING STRAIT ESKIMOS ARE BOTH PHYSICALLY AND MENTALLY THE HIGHEST TYPE OF THE WESTERN ESKIMOS. WHEN OOGANEESEE TAKES A HUSBAND SHE WILL BE WED IN THE WHITE MAN'S CONVENTIONAL WAY, NOT IN THE TRADITIONAL WAY OF HER PEOPLE.

of the white man highly incensed the girl and her parents as well. This attitude is not so prevalent among the mar-

[8] "Folk Tales of the Western Eskimos," by Clark M. Garber.

ried women, yet their chastity may, in many cases, be purchased for a few trinkets. However, in my examination into the effects of deceased Eskimo women, I have found numerous trinkets, such as buttons from sailors' uniforms, beads, brightly colored glass trinkets, etc., which indicate a rather frequent adulterous cohabitation with white men. I have also been informed by many of the old men that the white sailors often took their wives from them by force and by first getting the men insensibly drunk. Although the crossing of bloods usually takes place between white men and Eskimo women, I know a number of cases in which white women have crossed their blood with the blood of Eskimo men.

Polygamy, Monogamy and Polyandry

Polygamous marriages are by no means uncommon among the western Eskimos, but as a general rule the Eskimo is monogamous. There are many cases in which a chief or medicine man becomes affluent to such a degree that to maintain his prestige and large household he must have a second or third wife. If a man's wife should prove incapable of bearing children, or if she should bear only female children, it is his privilege to take a second wife for child-bearing purposes, while the more menial tasks are relegated to the first wife. The practise of infanticide, with special reference to female children, regulates the number of women in the colony, and the practise of infanticide in turn is regulated by economic conditions, such as famine and starvation. During the lifetime of an Eskimo mother it is not uncommon for her to bear as many as ten or twelve children, of which number a possible four or five may reach maturity. In some of the remote colonies where primitive life still prevails, the infant mortality rate often reaches 75 per cent. Murdock found,[9] "As is the case with Eskimos, most of the men content themselves with one wife, though a few of the wealthy men have two each. I do not recollect over half a dozen men in the two villages who had more than one wife each." Throughout their legends and stories the western Eskimos make many references to the polygamous marriage. To them a man who could afford two wives was indeed a great man, and the man who had three wives was looked upon in a worshipful attitude, not because of the three wives, but because he must be the acme of power and wisdom.

In this connection allow me to cite a case of a most unusual nature, one which lies within the author's experience. Upon arriving at a primitive coastal village I was met by an Eskimo man who was apparently about fifty years of age. This man seemed very anxious to have private conversation with me, so as soon as my dog team was properly cared for he was given the opportunity to make his wants known. Being their atanak (big chief) they depended upon me for advice in all matters, even in their domestic affairs. This man wished advice upon the following proposition. It appears that he had married a girl who was about sixteen, whereas he was between forty-five and fifty. She bore one child for him, after which he apparently became sterile. His inability to produce more children weighed heavily upon him, because to die without leaving plenty of children would be a very bad thing. He therefore wished my approval on a plan which he had evolved to alleviate his childless situation. He proposed to induce a healthy young man of the village to live for a time at his home and to cohabit with his wife until she should be with child. Because I

[9] Murdock, Ninth Annual Report, Bureau of American Ethnology, p. 411.

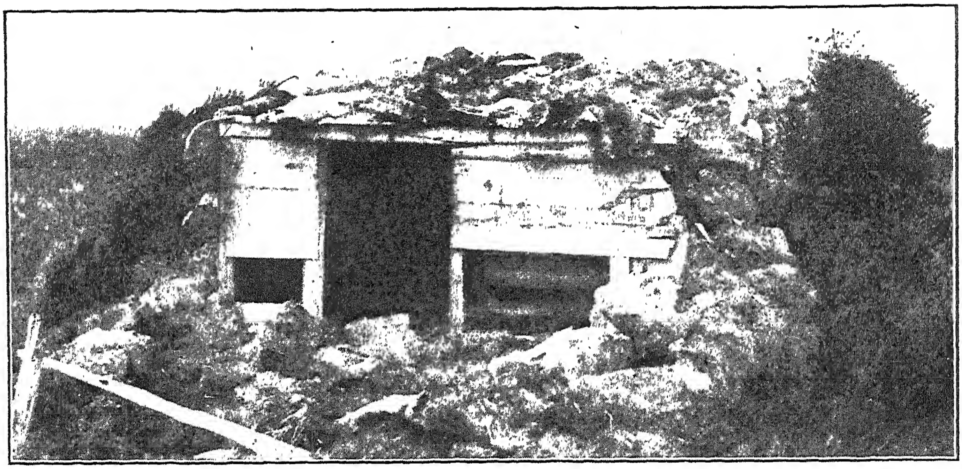
realized what such an arrangement would mean in the way of domestic happiness I gave my approval. On two separate occasions did this take place, resulting in the birth of two fine boys to the young wife. Thereafter the young man accepted his fee from the proud husband, and before long had a wife and family of his own. The tradition that a man must not die childless is, without a doubt, largely responsible for the existence of the Eskimo race to-day. This same sort of problem had been solved by many others in the same manner, so I was informed by the man whom I had favored. Here again we find concrete support for the statement that all the Eskimos' traditions and customs which have to do with sex, marriage and childbirth function toward one purpose—the propagation and perpetuation of the race. In this case we have seen a domestic difficulty solved in a primitive, but most logical and economical way.

Polyandry is much less common among the western Eskimos than polygamy. I have known several cases of polyandry, but always the people were beyond the age of reproduction. This is accounted for by the fact that there is more often a shortage of females than of males. Some authors believe that Eskimo women live much longer than men, basing their belief on the fact that men are exposed to greater hardships and stronger devitalizing factors during their lifetime. On the other hand, we must take into account the fact that an equally large number of Eskimo women die early in life as a result of childbirth, post-partum hemorrhage and infection. Furthermore, Eskimo women show the symptoms of old age much earlier in life than the men, because they have suffered the ravages of many childbirths and the devitalizing effect of suckling their children until they are four and five years old. As far as the practise of polyandry is concerned, I am confident that such cases are exceptions rather than customary. If two men marry and live with one woman the cause is an economic one. Every Eskimo man must have a woman to sew his garments and make his muklucks. If there is a shortage of women, then one woman must serve two men in that capacity.

Divorce

As a rule marriage, when once consummated by childbirth, is a permanent relation. However, marriage ties are just as easily broken as they are made. No special ceremony is required in case a divorce is necessary or desired. If a man find his wife to be a nag and scold he needs but expel her from his innie and send her back to her parents. I have observed that most cases of divorce and separation occur between older men and women, *i.e.,* widowers who have married widows. A man who marries a woman who bears children for him will endure much nagging and scolding before he will expel the mother of his children from his innie. Also the mother of a family will stand much abuse before she will leave her husband and children. In their children they have a common interest, which results in greater tolerance and in most cases develops into a real affection between man and wife, and in both of them for their children. Space does not permit a disclosure of the innumerable ramifications of the Eskimos' domestic relations. It will suffice to say that children, especially boys, represent the criterion of a happy home. The absence of children breeds discontent and ultimately divorce, or the marriage of a second wife for childbearing purposes. Regarding divorce, Murdock says,[10] "Easy and uncere-

[10] Murdock, Ninth Annual Report, American Bureau of Ethnology, p. 412.



TYPE OF DWELLING OCCUPIED BY THE ESKIMOS

OF THE YUKON AND KUSKOKWIM DELTA. A SKELETON FRAMEWORK OF DRIFTWOOD, COVERED WITH BLOCKS OF TUNDRA SOD. THE SOD WALLS OF THE ENTRANCE WAY HAVE FALLEN DOWN, AND MUST BE REBUILT WHEN THE HOME IS AGAIN PREPARED FOR WINTER. IN THIS 9′ × 12′ DWELLING LIVES A FATHER, MOTHER AND FOUR CHILDREN. WHEN THE SPRING THAWS ARRIVE THE SOD ROOF AND WALLS DRIP WATER INSIDE SO THAT THE HOME BECOMES A VERITABLE MUD-HOLE OF FILTH. THIS TYPE OF INNIE IS MUCH INFERIOR TO THOSE BUILT BY THE INNUITS OF THE ARCTIC.

YUTE MAN AND WIFE FROM THE KUSKOKWIM RIVER

THE SPARSE BEARD AND PRONOUNCED MUSTACHE OF THE KUSKOKWIM RIVER ESKIMO ARE HIS MOST DISTINGUISHING CHARACTERISTICS. THEIR COMPLEXION IS SOMEWHAT LIGHTER THAN THOSE OF THE ARCTIC, AND THEIR STATURE A LITTLE SHORTER. APPROXIMATE AGES 50 YEARS EACH.

monious divorce appears to be the usual custom among the Eskimo generally, and the divorced parties are always free to marry again.'' The folk tales of the western Eskimos are veritably full of references to divorce, separation, marriage, sex and childbirth. To them such things were no more improper than the simple process of wicking the seal-oil lamp. They were common, everyday occurrences in their lives, and they looked upon them in no other sense. Joking and badinage about sex and domestic life had no more significance than joking about the failure of a hunter.

Inbreeding

Until the ingression of the white man the Eskimo did not realize the benefit of blood-crossing. It was, and is to-day in the primitive villages, traditional that marriages should be confined to the immediate locality. In their folk-tales they frequently refer to the mating of young men and women with strange people in faraway places. The characteristic legendary outcome of such marriages is unhappiness and often tragedy. In view of the fact that their traditions and folk-tales go hand in hand it is not difficult to deduce that marriages with strangers from other and distant villages were frowned upon. In an effort to determine the extent of inbreeding the writer attempted to trace the genealogical connections of a prominent Eskimo family on the Kuskokwim River. The result showed that every other Eskimo family in the colony and vicinity was closely related to this family. It is common for cousin to marry cousin. I have known cases where uncles married nieces, and aunts married nephews. And it is not extremely rare that brother married sister. In four cases of which I have record a father married his daughter. Such close intermarriages are frequently mentioned in their legends and stories, but always with a large degree of distaste and condemnation. No penalty is attached to the marriage of a father with his daughter, etc., but it is strongly disapproved and unfavored by the people.

Celibacy

Celibacy, as a virtue, has never been adopted by the Eskimo people. Unless there is a marked shortage of women in the Eskimo colony not even the poorest man need be without a wife. Such shortages of females have occurred in times past and once during the author's life among the western Eskimos. The chief cause is the destruction of female babies as an economic measure during times of famine and starvation, so that not enough of them reach maturity. To overcome this difficulty a polyandrous arrangement was developed by which one woman would serve two men. In the 120 Eskimo colonies visited by the author not a single instance of celibacy was discovered. It may therefore be safely concluded that celibacy was unknown among the western Eskimos.

Exchanging and Loaning Wives

The exchange and loaning of their wives is a custom which is practised not only by the western Eskimos, but it is found among many of the earth's primitive peoples. It may take place as an amusement, as a matter of deference and hospitality shown to distinguished visitors, or the reason may be a practical one. Among the western Eskimos all three of these factors are responsible for the practise. In the region of the Yukon and Kuskokwim Delta the author frequently found himself honored by a village chief offering his wife as a bedfellow during the duration of the visit. This was his customary way of showing his respect and hospitality to visitors prominent among his people. Refusal of this offer is a base insult, which can

be assuaged only by presenting the host with a very fine gift. Murdock[11] speaks in the following manner concerning this practise among the Point Barrow Eskimos, "A curious custom, not peculiar to these people, is the habit of exchanging wives temporarily. For instance, one man of our acquaintance planned to go to the rivers deer-hunting in the summer of 1882, and borrowed his cousin's wife for the expedition, as she was a good shot and a good hand at deer-hunting, while his own wife went with his cousin on a trading expedition to the eastward. On their return the wives went back to their respective husbands. The couples sometimes find themselves better pleased with their new mates than with the former association, in which case the exchange is made permanent."

Among the Eskimos of Bering Strait, when the chief of one village visited the chief of another village, his host always loaned him a wife for the duration of his visit. If more than one person came to visit at the same time a consort was provided for each of them. This custom is often mentioned in their folk-tales. For instance, in the Legend of the Magic Pooksak we find a direct reference to this custom.[12] "The three wives of the famous chief Pumimyouk had been given to the visitors to be their partners or mistresses during their visit at Engyukarik. When the feast was over the three women departed each taking the man she had fed."

Jealousy

Jealousy among the western Eskimos, as among all people, is based upon the desire for exclusive possession of the mate. Westermarck[13] says, "Among the Eskimos the jealousy of the men seems to be feebler than among most other natives of America; but it is not absent." I have found during my life with the primitive and semi-civilized western Eskimos that the jealousy of the men and also the women is rather pronounced. After a wife is taken and children are being produced, the husband jealously guards the chastity of his mate. Jealousy in the Eskimo husband begins as soon as he has taken a wife in probationary marriage, and when proof of his wife's fecundity has been attained he demonstrates a deep concern for her chastity. While the young men and women of the village exercise sexual freedom prior to marriage there is little evidence of jealousy among them other than that of a petty nature. In a number of cases which I have observed the best girls of the village who would make the most likely wives were freely satisfying the sensuous desires of the young men, yet there was no evidence of jealousy among them. But as soon as one of these girls was taken to wife her husband constantly guarded her against the approaches of any of her former paramours. Even in polygamous marriages the same concern is shown regarding the chastity of all wives. This accounts in a great measure for the custom of the young husband leaving his wife with her parents or taking her with him to an isolated camp. Eskimo wives are equally jealous of their husbands, especially if the husband is a famous hunter and good provider.

Let me here cite an instance which will illustrate clearly the Eskimo husband's jealousy. In a village on Bering Strait there lived a man who was the husband of a fine type of Eskimo woman and the father of six equally fine children. There also lived in this village a man who, because of his previous relations with white people, had acquired a considerable degree of sexual licentious-

[11] Murdock, Ninth Annual Report, Bureau of American Ethnology, p. 413.

[12] "Folk Tales of the Western Eskimos," Clark M. Garber.

[13] Westermarck, "The History of Human Marriage," Vol. I, p. 307.

ness. By reason of his superior intelligence most of the men feared him and would tolerate his tampering with their women, regardless of their jealous hate of him. One day upon returning from his trap lines, the father of this fine family learned that this sexual pervert had cohabited with his wife. The violation of his wife right before his own family so stimulated and wrought upon his animal instinct of mate protection that he came to me in a great frenzy of jealous hate and demanded that I give him permission to eliminate the offender. Upon my refusal, the wronged husband informed me that if this man visited his wife again he would kill him, whether I gave my consent or not. Murders have been committed and feuds thereby started as a result of jealous rage on the part of Eskimo husbands whose wives have been incontinent.

In concluding this discussion the author wishes to stress the point that the acquisition of accurate ethnological data concerning the western Eskimo depends on the actual observation of the manifestations of their life process. In our day it is rarely possible to find a native people whose life is untouched by European influences. To acquire ethnological information of value concerning such natives the ethnologist must have the ability to differentiate between the material resulting from European influence and the purely native culture. He must be prepared to go and live for a time among the natives whom he would study. He must go among those natives where the European influence has not been felt, or where it has been felt the least. And it is no less important that he go with a clear understanding that to emphasize race difference will cause the natives to despise him. Only by adapting himself to the simple life of the native people, by gaining their utmost confidence, will he be successful.

EVOLUTION OF THE USE OF THE MODERN MATHEMATICAL CONCEPT OF GROUP

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WIDELY different meanings are ascribed to the mathematical concept of group in our current dictionaries and encyclopedias.[1] Some of these are so general that a large number of apparently fruitless systems of abstract elements come thereunder. For instance, the three elements represented by 1, 2, 3 have been called a group[2] when their combinations are determined by the following elementary table:

$1 \cdot 1 = 1$	$2 \cdot 1 = 3$	$3 \cdot 1 = 2$
$1 \cdot 2 = 3$	$2 \cdot 2 = 2$	$3 \cdot 2 = 1$
$1 \cdot 3 = 2$	$2 \cdot 3 = 1$	$3 \cdot 3 = 3$

Hence these elements obey the commutative but not the associative law when they are combined by multiplication, and the table may therefore be of interest even to the student of elementary algebra as an illustration of the nature of the associative law in multiplication. It is, however, questionable whether the term group should be available for speculations which are so foreign to what is commonly regarded as useful mathematics as contrasted with mathematical recreations.

Those who are especially interested in group theory would naturally like to maintain the respect for this subject which it has secured by its wide usefulness. To do this it seems desirable to insist on a definition which excludes matters of little or no importance and which is also sufficiently restrictive to give rise to extensive developments. Such a definition was given more than forty years ago and can be expressed in the following brief form: A given set of distinct elements is a group if they obey the associative law when at least three of them are combined, two at a time, and which are such that if two of the symbols in the equation $xy=z$ are replaced either by one or by two elements of this set, the resulting equation has one and only one root in the set. In what follows we shall assume for the sake of definiteness that the term "modern mathematical concept of group" implies either this definition or one which is equivalent thereto, unless the contrary is explicitly stated.

This definition is obviously somewhat more complex than the supplemental one which was at first used in connection with the theory of substitutions, *viz.*, that a set of distinct substitutions is a group if it includes the square of every one of them and also the product of every two. It should, however, be observed that the three elements noted in the first paragraph satisfy this definition of a substitution group. What is more important is the fact that the definition noted at the close of the preceding paragraph has led to developments of such extensive usefulness with respect to abstract elements that it seems to have justified itself by experience. While the condition that a set of elements contains the square of every one and the product of every

[1] In Webster's New International Dictionary, including the second edition (1934), there appears under the entry "distribution" the following statement which is misleading from the standpoint of mathematics: "Arrangement of objects in classes called *parcels* when the order is indifferent, and *groups* when it is essential." The direct definition which appears under the entry of "group" in this dictionary is inadequate as regards the theory of abstract groups but is useful in the study of certain sets of concrete elements, where it becomes a supplemental definition.

[2] J. Perott, *American Journal of Mathematics*, Vol. 11 (1889), p. 101.

two has also proved to be very fruitful when applied to certain concrete elements it has little value with respect to an abstract theory as is illustrated by the cited example.

One of the most striking facts in the history of group theory is that in the study of concrete elements some writers imposed certain fructifying conditions and spoke later of these added conditions as if they were the characteristic properties of a group. This procedure was followed in the beginning of the subject as regards the theory of substitutions and was employed later even as regards less restrictive sets of elements. Since it has been the source of much progress it should not be condemned, even if it has also been the source of much confusion. It seems, however, reasonable to strive to secure progress without confusion in this as well as in other fields of scientific endeavor, notwithstanding the fact that progress with confusion is more desirable than no progress. At any rate, it is of some interest to trace the early use of a concept in its restricted form even if the nature of these restrictions were not emphasized at the time and were not formulated until thousands of years had elapsed since the concept was first used.

The use of the group concept has a much longer history than its definition and hence the present article relates to much earlier developments than the one which appeared in a previous number of this periodical[3] under the title, "Evolution of a Modern Definition of the Mathematical Term Group." In an implicit form the modern concept of group underlies the prehistoric divisions of the day into equal parts, such as its division into 24 hours, where 24 is a kind of modulus in the modern sense of the word and constitutes a type of zero with respect to addition. The use of this type of zero is much older than the use of a special symbol for zero as a number and *the addition group with respect to an implied modulus is one of the earliest instances of the use of the modern mathematical concept of finite group,* which emerged slowly from an implicit to an explicit concept.

A somewhat trivial example of the prehistoric use of this concept is furnished by the operation of subtracting from unity. It is well known that complementary fractions, that is, fractions of the form $1/n$ and $(n-1)/n$, play a prominent rôle both in the language and in calculations of the ancients. The two fractions $\frac{1}{3}$ and $\frac{2}{3}$ are especially noteworthy along this line, while $\frac{1}{2}$ is its own complement. Special symbols appear in the ancient Egyptian as well as in the ancient Babylonian literature for a few of these complementary fractions, and they seem to have been regarded very early as being on a par with the system of unit fractions. In this connection it is to be emphasized that two complementary fractions constitute a group of order 2 with respect to the operation of subtracting from unity. The operation of dividing unity by a given number later gave rise also to the group of order 2 and when these operations were combined still later they gave rise to the important group known as the anharmonic ratio group.

The earliest examples of the concept of group of infinite order in the modern sense are also prehistoric. One of these is furnished by the totality of the positive rational numbers when they are combined by multiplication. The development of these numbers has been regarded as the main mathematical objective of the two leading pre-Grecian mathematical civilizations, *viz.,* those of the ancient Babylonians and the ancient Egyptians, but it was only partially attained by them, although the former made much more progress in this direction than the latter as a result of their development of an approximately positional system of arithmetic having 60

[3] Sci. Mo., 39: 554–559, 1934.

for its base.[4] One of the striking features of this system is that it has no symbol which separates the integers and the proper fractions when they are represented systematically, corresponding to our modern decimal fractions.

While some groups in the modern sense of this term were used in prehistoric times the claim that there existed a prehistoric group theory, which is emphasized in the introduction to the second edition (1927) of A. Speiser's widely used "Theorie der Gruppen von endlicher Ordnung," can not be said to be as yet fully established even if many of the early ornaments seem to point to a domination of the group concept in view of their types of symmetries. There are many evidences pointing to the influence of the concept of symmetry on the early mathematical developments. In particular, several of the quadratic equations in one unknown considered by the ancient Babylonians resulted from the combination of two symmetric equations in two unknowns in the forms of $x+y=a$ and $xy=b$, respectively, and the first proposition of Euclid's "Elements" relates to the symmetric equilateral triangle. There is, however, a long step from an emphasis on symmetry to the development of a group theory in the modern sense of this term.

Special subgroups of the group of movements of space were also employed implicitly in prehistoric times. For instance, the group of rotations around a fixed point was naturally suggested by the daily apparent movements of the sun and the seasonal changes of the weather. In a world which is so replete with groups as ours is the development of scientific thinking naturally led to a consideration of certain groups, but these were not known to be sufficiently abundant to merit a special theory before the latter part of the eighteenth century, and then only because they furnish a means of classifying functions which are useful in the study of the algebraic equations in one unknown. It is then that a stone which had been previously overlooked by the builders of mathematics was made a cornerstone which has since then been used with increasing appreciation.

The main object of the present article is to direct attention to the *evolution* of the use of the modern mathematical concept of group. In the ancient groups to which we have referred this evolution was usually completed in prehistoric times, and these groups are of less interest in the present connection than those whose evolution was completed in historic times. One such group is the modern addition group embodying the use of both zero and negative numbers. This group was not completely developed until after the beginning of the Christian era. In fact, it was not used even by the ancient Arabian mathematicians although the Hindus had employed it earlier with some success. It was naturally used with some hesitation before the use of the negative numbers in multiplication was explained satisfactorily about the beginning of the nineteenth century even if its theory did not directly depend upon this explanation.

Another group whose evolution was completed in historic times is the one now commonly known as the group of movements, which is intimately connected with the foundations of elementary geometry. As positive and negative movements are considered therein it is very closely related to the addition group to which we referred in the preceding paragraph. This group is especially interesting in the history of mathematics because the study of all its subgroups by C. Jordan (1838–1922) constitutes the earliest extensive direct use of groups of infinite order (1867). Before

[4] O. Neugebauer, "Vorlesungen über Geschichte der Antiken Mathematischen Wissenschaften," 1: 203, 1934.

the zero movement and negative movements were considered various groups of movements with respect to a modulus, and semigroups of movements corresponding to semigroups of addition, engaged the attention, at least implicitly, of those who developed mathematical subjects. The later evolution relates largely to the emphasis on the identity (zero movement) and the inverses (negative movements) in the group of movements.

An elementary group whose evolution belongs to a comparatively recent period is the group of multiplication, modulo m, whose elements are the natural numbers which are not greater than a given natural number m and prime to m. This has been called the most important example of abelian groups of finite order[5] and was first employed effectively by L. Euler (1707–1783). It should be observed that this abelian group was employed (1760–1) before J. L. Lagrange (1736–1813) studied substitution groups in connection with his theory of the solution of algebraic equations, but the latter work influenced the early development of group theory more than the former, as a result of the fact that the theory of substitution groups received attention before that of abstract groups. J. L. Lagrange used the concept of holomorph of a cyclic group.

Not only were various groups in the modern sense of this term used by the ancient and the medieval mathematicians, but these also began early to observe evidences of the (1, 1) correspondence between two of the most important ones of them, *viz.*, those formed by a general arithmetic progression and by a general geometric progression, respectively. This made it possible to coordinate the fundamental operations of addition and multiplication and gave rise later to the use of logarithms during the seventeenth century, a subject which has ever since then been highly regarded, especially in those applications which involve lengthy numerical calculations. It is an interesting fact that J. Napier (1550–1617) did not make the identities of these two groups correspond when he constructed his so-called tables of logarithms by means of a certain (1, 1) correspondence between these two groups.

Hence his tables were soon replaced by others in which the identities of these two groups correspond, and on this account the latter are more convenient. It is a striking fact that this important feature of the history of logarithms has been commonly overlooked by the writers of general histories of mathematics up to very recent times. The first such history in which it is explicitly noted seems to be that of J. Tropfke's "Geschichte der Elementar-Mathematik" and here it did not appear before the third edition of volume 2 (1933), page 206. The history of the logarithms becomes much clearer when this point is emphasized and the subject of group theory thus exhibits its usefulness as a suggestive and coordinating theory extending down to the most elementary parts of mathematics. Implicitly it was a dominating concept long before the nature of this domination was explicitly noted.

The (1, 1) correspondence between the groups formed by the general arithmetic progression and the general geometric progression began to be noted by the ancient Greeks, in particular, by Euclid and Archimedes, as regards the product of numbers expressed as powers of the same number. This seems to furnish the oldest example of a (1, 1) correspondence between two infinite groups and is important because the (1, 1) correspondences between groups constitute now a fundamental problem in their theory. These correspondences are now commonly known as simple isomorph-

[5] H. Weber, "Lehrbuch der Algebra," vol. 2 (1899), p. 60.

isms, and they were not studied as a special subject before the second half of the nineteenth century. The idea of simple isomorphisms underlies the development of abstract numbers and hence it is one of the primitive notions in the development of mathematics. The fact that it did not receive a special name before the explicit use of group theory is another evidence of the fact that definitions of concepts have frequently lagged far behind their use in the development of mathematics.

There are three stages in the use of the modern mathematical concept of group which should be noted. The first of these relates to the period when this concept was used without any definition of the term group. This period extends into the first half of the nineteenth century. It was followed by a period of much greater mathematical activity during which the concept was used as a supplemental concept with respect to concrete elements. This period extends up to the latter part of the nineteenth century, when various writers began to use the concept as an independent concept, while others continued to use it as a supplemental concept. The writings of E. Galois (1811–1832), A. L. Cauchy (1789–1857), C. Jordan (1838–1922), S. Lie (1842–1899), F. Klein (1849–1925) and H. Poincaré (1854–1912) illustrate this use of the group concept, and they contributed most forcibly towards popularizing this concept by exhibiting its wide usefulness in establishing contacts which had theretofore escaped explicit notice. These writings illustrate a striking feature of the devolpment of the mathematical language, *viz.*, the use of terms which are only partially defined and which gain in content with the advances in the fields to which they relate. The term mathematics itself is another example of such a word.

The third stage in the use of the modern mathematical concept of group is represented by systems of postulates which make it possible to use the concept with respect to abstract elements and thus to construct an abstract theory of groups. The rapid growth of this theory is due to the fact that many of its fundamental theorems had been developed under the influence of the supplemental definition of the term group and required only a slight change of language to be available for the abstract theory. Just as in other parts of mathematical development, so here unexpected richness of results came into mathematics not so much because their sources were diligently sought by the investigators but because they unexpectedly forced themselves on their attention. In the words of F. Klein,

> One cannot repress that oft recurring thought that things sometimes seem to be more sensible than human beings. Think of it; one of the greatest advances in mathematics, the introduction of negative numbers and of the operations with them, was not created by the conscious logical reflection of an individual. On the contrary, its slow organic growth developed as a result of intensive occupation with things, so that it almost seems as though men had learned from the letters.[6]

Groups are among the things which sometimes seem to be more sensible than human beings, for they have frequently suggested properties which had not been suspected both as regards their own structure and as regards the concrete objects to which they were applied. The inherent suggestiveness of mathematics is clearly illustrated also by the extension of the number concept through the study of all the possible roots of algebraic equations. While this inherent suggestiveness relates to a variety of mathematical subjects it is especially pronounced in group theory so that H. Poincaré was led to say near the close of his brilliant career, "The theory of

[6] Felix Klein, "Elementary Mathematics from an Advanced Standpoint," Vol. 1, p. 27, 1932.

groups is so to say the whole of mathematics divested of its matter and reduced to pure form." Such outbursts of enthusiasm are unusually common in the literature of group theory and exhibit its attractiveness when its various applications are fully comprehended.

Since the concept of groups is now in the final stage of its metamorphosis towards the abstract and has in recent times passed rapidly from the stage of an undefined concept to one which was at first used only with a supplemental definition, it presents at present an interesting subject also from the standpoint of mathematical history. These changes help to explain the widely different definitions of this concept adopted by recent writers and make it somewhat difficult for those who are not specially interested in this field to decide which of these definitions they should use. It should, however, be emphasized that it seems more desirable to adopt one which is in line with the abstract towards which the trend is moving than one which is based on the supplemental idea from which the trend is moving away. The emphasis here is, however, on the fact that we have before our eyes in contemplating this concept an interesting example of the metamorphosis towards the abstract of a mathematical concept, which may be of interest to the student of the devolpment of scientific thinking.

It may be of interest to refer in closing to a recent extension of the modern mathematical concept of group. If a set of h distinct group elements, s_1, s_2, . . . , s_h, has the property that it contains the product of every two of them, including the case when these two elements are equal to each other, then this set is called a group of order h. An obvious extension of this concept is that the set includes the product of every $n+1$ of these elements, including repetitions, but does not include the product of a smaller number of them. In the special case when $n=1$ this reduces to the one considered above but for all larger values of n it follows that the set is not a group but a co-set of a group of order nh with respect to an invariant subgroup of order h. While the term co-set was introduced to represent a supplemental concept relating to a group it results from what precedes that the concept of group may also be ragarded as supplemental to that of co-set. Such a co-set becomes really fruitful only when it is considered in connection with the related group and hence the latter dominates here also.

ISOSTASY

By Dr. WILLIAM BOWIE

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WE usually confine our engineering thoughts to such structures as bridges, buildings, dams, tunnels, highways, power projects, etc., but I like to extend engineering thought to the earth as a whole. We really do not give very much consideration to the old earth and what has been going on in its interior and at its surface during the past billion or so years. I speak of billions of years. I think I am justified in this, for according to all the geological and geophysical evidence the earth's surface began to be disturbed about a billion six hundred million years ago. It was then that erosion and sedimentation began. We haven't the slightest indication of what was going on prior to that time, but it is reasonably certain that at the beginning of what we may call the sedimentary age the earth's surface was irregular. There were great areas that were depressed and others that were elevated. The hollows or low places were filled with water forming oceans and seas, and the high land projected above the water to form continents and islands.

What caused the irregular surface of the earth originally? No one knows. There have been many hypotheses advanced, but most of them are very unconvincing. The best one of these hypotheses, according to my view, is that which calls for the formation of the moon by a disruption of a portion of the earth. If an outer shell of the earth had solidified and its period of rotation had become such as to synchronize with the natural elastic period of the earth as a whole, then perhaps the mass would have been unstable and a drop would have been thrown off, that drop being the moon.

It is rather interesting to note that the density of the moon, 3.4, is just about the density of crustal rock on the earth. The volume of the moon is about equal to the volume of crustal material, over the areas of the oceans, approximately one hundred forty million square miles, to a depth of thirty or forty miles. It is possible that the moon may have been thrown away from the earth and that the great scars which were left are now occupied by the oceans.

In any event, we know that a billion and a half years ago the earth's surface was irregular. If it had not been irregular, the water now forming the oceans would have been at a uniform level over the whole surface and, therefore, there could not have been any such thing as erosion and sedimentation.

The Coast and Geodetic Survey has taken an active part in testing a very interesting idea to the effect that the earth is composed of materials of two characteristics. The first is a great inner body which is apparently solid but with no residual rigidity; that is, it will change its form without breaking under stresses that act for long periods of time. The second material composes the crust or outer part of the earth. It has been found by the analyses of geodetic data that this crust extends to a depth of approximately sixty miles below sea level. The crustal rock has residual rigidity. It breaks if the stresses exerted on it are too great.

The crust is like a huge blanket sixty miles in thickness and 197 million miles in area wrapped around the earth. The geodetic data show that this blanket is resting on the interior material very much as an ice sheet is resting on a lake or on the Arctic Ocean.

There have been enormous quantities

of material eroded from continents and carried down to tidal waters. An estimate by the scientists of the U. S. Geological Survey is to the effect that a blanket of material one foot in thickness is carried from the United States to tidal waters each nine thousand years. This means that at that rate a mile of erosion would occur in approximately forty-five millions of years. Since the sedimentary age is thirty times that long, there may have been thirty miles of material eroded from the United States, if the area was maintained at its present elevation.

It is, of course, unlikely that any such amount of erosion could have taken place from any one spot. As erosion occurs in a mountain area the crustal blanket is lightened at this point. It doesn't press down on the nucleus quite so heavily and, therefore, the nucleus, yielding to these stresses, will well up under the area of erosion and push the crustal material upward. Where the sediments have been deposited the crustal blanket becomes extra heavy and it pushes down on the subcrustal material, which yields and moves to the side, just exactly as water would be displaced if an ice cake or a portion of an ice field were weighted down by an added load.

Sediments have been deposited during so-called geological time to thicknesses of as much as 40,000 feet, nearly eight miles. One can imagine what a great load that is and how the crust beneath would break or yield under it. There is evidence that in the past mountain areas have been completely leveled off. This has required much more material to be carried from the mountain area than the amount above sea level to begin with. If the density of the subcrustal material that enters crustal space is 10 per cent. greater than that of the surface rock, then it can easily be shown that ten times as much rock as that contained in the mountain must have been eroded to bring it to sea level.

It is also of interest to note that every plateau and every mountain mass has been formed in areas that have been previously subjected to great amounts of sedimentation. There must be some close relationship between uplift of portions of the earth's surface and sedimentation.

There is hardly a spot on the earth's surface that has not been below sea level at least once. This is indicated by the presence of fossils of marine animals in the stratified rocks. This process has not been finished. It must be going on to-day and it will continue to go on as long as we have sunshine and rain. The heat from the sun evaporates water which falls to the surface of the earth as rain. After every rain some material is carried from high to low areas as sediments or as matter in solution. While the process of wearing down a mountain or plateau is slow, yet there is plenty of time. A billion and a half years is quite a long period.

The earth should not be considered as a rigid structure. It is a yielding one. As loads are shifted at its surface the crustal blanket will go up or down according to whether it is eroded or overloaded. It is remarkable how nearly the crustal blanket is in equilibrium in all its parts. *Isostasy* is a term meaning equal pressure and is used to express the equal pressure of the earth's crust on the inner material. Of course, we do not expect each small portion of the earth's crust, say a mile or ten miles square in cross section, to be in perfect isostatic equilibrium, but if we could cut up the earth's crust by vertical planes into blocks approximately one hundred miles square, and if there were no resistance, frictionally or otherwise, to the blocks moving up or down, we should expect the movement of any one block to be very small, measured perhaps in hundreds of feet, certainly not in thousands.

The basis of this opinion is, of course, the vast quantity of geodetic data that

has been accumulated in this and other countries. We determine the longitude and latitude of thousands of points over the earth's surface by means of triangulation, and we observe the astronomical latitudes and longitudes at some of those places. When we compare the astronomical and so-called geodetic latitudes and longitudes, we find that in many cases they differ greatly. Some of them differ as much as thirty seconds of arc, a difference corresponding to as much as a half mile on the earth's surface. We know that the irregular surface of the earth has an effect on astronomical observations. All the astronomical work is referred to the direction of the plumb line, which is at right angles to the levels of the astronomical instruments. At different points on the same degree of latitude the plumb line does not point to the same spot on the axis of the earth. This is because the direction of gravity is influenced by the irregular terrain. A great mountain mass will deflect the plumb line toward it.

We have some notable examples of deflections of the vertical. One in our own area is on the Island of Puerto Rico. Two astronomical stations, one on the south and the other on the north coast of that island, were joined by triangulation. It was found that the exact distance determined by triangulation was just about a mile shorter than the distance computed from the difference in latitudes of the two astronomical stations.

We can correct the astronomical observations for the effect of the irregular surface of the earth. The masses above sea level will attract the plumb line, while the deficiencies of mass in nearby oceans will, in effect, repel the plumb line. After we make the corrections for the irregular surface of the earth, however, we find that the astronomical and geodetic latitudes and longitudes still stand apart. The corrected values differ in the opposite sign from what they did originally. It was this discrepancy that led to the thought that there must be a deficiency of density under mountains and plateaus and an excess of density under oceans. These compensating masses were assumed to be exactly equal to the masses of the topography, either positive or negative. A quantitative test of this theory was made by engineers of the Coast and Geodetic Survey some thirty or more years ago. When the effect on the plumb line of the compensating deficiency or excess was applied to astronomical observations, the astronomical and geodetic longitudes and latitudes were found to be very nearly the same. There were still some outstanding differences, but it has since been found that those differences are probably largely due to buried structure such as masses of igneous rock fairly close to the stations, or to great troughs filled with material of less than normal density that in effect repel the plumb line.

In addition to the astronomical stations we have values of gravity determined at many places over our own and other countries. We find that the gravity values, representing the pull of the earth, are influenced by the irregular terrain just exactly as the astronomical determinations of longitudes and latitudes are affected. We bring the observed and theoretical values of gravity more closely into accord when we apply corrections for topography and for the isostatic compensation of the topography.

It seems reasonable to assume that a mountain mass such as the Rockies is compensated within 10 per cent. I am of the opinion that the compensation is even closer than that for areas a few hundreds of miles square.

The isostatic condition of the earth's crust has been taken into account by engineers and mathematicians of the

Coast and Geodetic Survey in deriving the dimensions for the mathematical surface that most nearly fits the sea level or geoid surface of the earth. If water covered the earth's surface everywhere to the same depth and there were no differences in the distribution of densities along the radii of the earth and if this water surface were undisturbed by tides and winds, the surface would be very nearly a true spheroid. Any meridional section would be an ellipsoid and any small circle parallel to the Equator would be a circle. Owing to the irregular surface of the earth, however, these curves are not true mathematical ones. They are somewhat irregular. It is not known definitely just how much these irregularities amount to, but probably they are not greater than several hundred feet at any place on the earth's surface. It is reasonable to assume that the geoid or sea level surface is below the spheroid over ocean areas and above the spheroid over the continents. In deriving the shape and size (figure) of the earth from triangulation and astronomical data, we get very much better values, that is, values nearer the truth when we apply the principle of isostasy.

It is interesting to note that forces do not pile up to tremendous proportions in the earth's crust. The crust yields frequently. We do not know how many earthquakes occur each year, but the number that is recorded by the few seismological stations in existence is something like ten thousand. This is about three hundred earthquakes per day. Of course, many of these are so exceedingly small that they could only be detected from the records of the seismological stations, but they show constant yielding. It is fortunate that there are many earthquakes, for if it were otherwise, stresses would be set up in the earth's crust that would be so tremendous in size that when a break eventually came the destruction would be far greater than it is now.

Earthquakes have caused great damage to the works of man and have caused tens of thousands of deaths, but this has been due largely to lack of preparation for them. A wooden house or a modern office building with steel framework is not seriously damaged by an earthquake, but other types of structures, if put up without braces and designed only to withstand the weight of the material and the forces of the wind, may be rocked to pieces when an earthquake occurs. It is not costly to put in diagonal bracing to keep the walls and floors of a building strongly connected during vibration of the structure by an earthquake. This matter of protecting buildings and engineering structures from the effects of earthquakes is receiving very serious consideration by engineers to-day, especially by those operating in regions where earthquakes are most apt to occur.

There are several causes of earthquakes of which we are quite sure. One is the pressing down of crustal material in areas that are undergoing very rapid and great sedimentation. As the load is piled on the crust it will at first yield elastically. No doubt there is some plastic movement of crustal material involved, but at times the weight becomes greater than the elastic limit of the rock and then a sudden break or snap occurs. An earthquake is really a train of waves that go out from the place where the break occurs.

A second cause of earthquakes must be the moving up of crustal material under an area subject to erosion. As the material is eroded from a portion of the crustal blanket it becomes lighter. The subcrustal material moves upward into crustal space to balance the underloading. Sometimes the movement upward is so great that the rock snaps instead of becoming distorted to relieve the stress. When this breaking occurs, we have an earthquake.

There is a third cause of earthquakes. An area that has been forced down

under sediments will eventually rise up to form a plateau or a mountain. In this process of going up, the elastic limit of the rock may be exceeded and the resulting break will cause an earthquake. We also have the case of a mountain or plateau area where great erosion has taken place. Eventually the erosion areas will sink below sea level and form geosynclines or troughs. This sinking sometimes causes rupture of the rock.

There are many phases of geology that are extremely interesting, such as volcanoes, or outflows of lava, the formation of dykes, the over-thrusting and underthrusting of rocks. Rocks are distorted in fantastic ways. It seems to me that engineers must work with geologists in order to discover just what is going on to change the configuration of the earth's surface and to cause all these very interesting phenomena. We should treat the earth as an engineering structure just as we would things that engineers build. We should search for causes of failure or yielding just as we would if a foundation started to give way.

I am confident that the cause of mountain and plateau formation is the change of density of the material of the crust below areas of sedimentation. Every cubic yard of crustal material under the sediments is pushed down into hotter regions, perhaps six or eight miles at times. Eventually the surfaces of equal temperature which have been depressed will rise to their normal positions. When they do the crustal material will become hotter and no doubt will take on new form or forms. There are many materials that appear in different forms and with different densities. Carbon occurs as a diamond, as coal and as graphite, with a very wide range of density. Quartz appears in many varieties with exactly the same chemical elements but with densities that vary as much as 6 or 8 per cent. Some of the feldspars having exactly the same chemical elements appear in different forms with quite large differences in density.

Why is it not possible for a change to occur in the density of some of the elements of the crustal material as this material is subjected to different temperature and pressure conditions? The old explanations for the formation of mountains and continents leave one rather confused, while this idea of change in density as the crustal material moves up and down seems simple and reasonable.

The question is frequently asked, what effect has all this movement of the earth's surface on surveying and mapping? The answer is that in some places it disturbs conditions very materially. In California, for instance, we find that some of our triangulation stations have been changed in their longitude and latitude by as much as ten feet, and along some of our lines of leveling bench marks have been changed by large fractions of a foot. Of course, there may be very great changes when an earthquake occurs. At Yakutat Bay, Alaska, the earthquake of 1901 made an extreme change in elevation of 49 feet. One can imagine what that would do to a river, highway or railroad.

We are now covering the country with arcs of triangulation and lines of levels, with the arcs and lines fairly closely spaced. Whenever an earthquake occurs we can go to the region where the break took place and rerun our lines of levels and reobserve the angles of the triangulation and determine just how much movement has taken place for each one of our stations. It will be interesting to learn how large an area is affected by an earthquake. Is it only a strip a mile or so wide or are hundreds or thousands of square miles affected? I am rather inclined to think that an earthquake is caused by forces of a very local nature, but I can not prove this. We shall have

to wait until we reobserve the triangulation and leveling that lie near the epicenters of many earthquakes.

I do not know just what happens to property lines when an earthquake occurs. In California, the earthquake of 1906 shifted fences in position by as much as ten or fifteen feet. Does the property line follow the fence or does the owner still have the same amount of area that he had before the 'quake? I believe that engineers of California have given some thought to the adjustment of property lines after earthquakes have moved them.

There seems to be very little evidence that the processes that operate on the earth's surface to change the configuration will end very soon. The earth's surface is certainly not getting very much colder than it was a billion years ago. Plant and animal life of those times could not have stood a temperature as great as that of the boiling point of water, 100 degrees Centigrade. I do not know what the average temperature of the earth's surface is now, but it can not be far from fifteen or twenty degrees Centigrade. We may assume that the earth's surface, if it has cooled down through the billion and a half years since rain began to fall and sediments formed, has not changed its temperature by as much as 100 degrees Centigrade. This is at a rate of one degree in approximately fifteen millions of years. This is certainly very slow cooling.

There is no need of our worrying about the earth and what is going on because we really can do little or nothing about it. Let us be philosophical and be thankful that we have many earthquakes instead of a few, that the sun shines and causes evaporation, that the rain falls and erosion and sedimentation take place. Let us not worry for fear the sites of our homes will be under the ocean some hundred million or so years from now. Surely any change in the configuration of the earth's surface will occur so slowly that the inhabitants of the earth will have time to move out of the way of anything that might cause them trouble.

THE GROWTH CURVE OF A SCIENTIFIC LITERATURE

NITROGEN FIXATION BY PLANTS[1]

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The Problem

One of the most obvious and yet almost neglected aspects of scientific research has been the accumulation of a technical literature. To label this literature "neglected" might appear to be a generous overstatement, in view of that constant demand for current periodicals and bound volumes in the majority of our scientific libraries, a demand that gives rise to that most irritating statement, "The journal you want is out." Appreciation of the literature, however, is confined primarily to its use as an additional tool for more research—it serves as a fountain of information and indicates guide-posts for present problems. While practically every scientist claims acquaintanceship with the literature of his particular field, his knowledge is usually restricted to the factual material contained therein. Study of the literature as an entity is almost completely unknown; its function in science is primarily that of a technical accessory—its meaning for the philosophy of research is little more than that furnished by gelatine plates, guinea pigs or graph paper.

It appears probable that this limited view of the function of publications might decidedly handicap the service of literature to general problems of science, however satisfactorily it meets the demands for mere technical assistance. At present, with the values of science seriously questioned by layman and official, an inventory of past and present activities is indicated to answer the recurrent questions of "Whither Science? Why? and How Far?" It is suggested that a study of the *biological properties* of the literature of various fields might provide one method of attack for the necessary inventory. By biological properties is meant the growth and development of a literature, especially as these are influenced by and reflected in the environment; subject-matter as well as size should be considered in evaluation of the data.

A census-taking of the publications in a given field should provide valuable information for the interpretation of past production and might afford some basis for prediction of future trends. Possible uses of an analysis based on the counting of heads among published papers would include the following:

(1) Provides an insight into the nature of the dependence of interest in a given problem upon external factors of an economical, political or emotional nature.

(2) Gives to the novitiate in a field an idea of the volume and distribution of the literature which forms the organic body of data to which he hopes to add.

(3) Enables a limited prediction with respect to future production of both number and content of papers. Awareness of future trends in production might allow a measure of control if this is deemed wise or necessary.

In order to lend itself to an analysis such as that proposed, the body of relevant material should possess certain characteristics. For example, interest in the subject-matter of the literature to be examined should have extended over a number of years. This insures that a

[1] Herman Frasch Foundation in Agricultural Chemistry, Paper No. 88.

more or less steady development rather than the mushroom type of growth has occurred. Likewise, the subject-matter should cover a fairly large but definite problem. The field should not be too sharply delimited; otherwise the volume of publications will not be sufficiently large to allow statistical treatment. On the other hand, unless the papers are concerned with a perfectly definite problem, the growth curve will represent the sum of a number of interlocking developments and as a result may defy rational analysis. Finally, the field of study represented by the literature being examined should be coherent and stable. If this is so, the research at a given time is intimately connected with past work and does not depend on the whim of the fad type of scientist.

Method of Attack

A body of literature that apparently satisfies the foregoing requirements is that which deals with the subject of nitrogen fixation by plants, especially by the *Leguminosae*. Because of the practical application, the literature on this subject boasts of an ancient and respectable lineage. A Chinese writer of the fifth century B.C. describes the use of the mung bean for green manuring. Reference to leguminous plants, likewise, are found in Egyptian writings of the pre-Christian era. Greek and Roman writers comment, often quite astutely, upon the importance and function of the *Leguminosae* in agricultural art. When in the early nineteenth century, agriculture was definitely regarded as a suitable field of inquiry for natural scientists, foremost among the contributions to the laws of husbandry were those concerned with the use of leguminous crops.

Albrecht Thaer, the foremost agriculturist of his day, strongly advocated the inclusion of the *Leguminosae* in crop rotation to the point of advising rotations in which leguminous crops predominated. So great was his influence that in 1856 he can state, "latterly the practice of sowing white clover with the last crop has become very general; only a few apathetic and indolent agriculturists, or men who are firmly wedded to old opinions and customs neglect this practice." Schultz-Lupitz, "the father of modern green manuring," urged the turning under of clover, lupines and peas for soil improvement. In America as early as 1801 Bordley writes in his "Essays and Notes on Husbandry and Rural Affairs": "Clover plowed in, together with the remaining of grain stubble, year after year will gradually meliorate the soil."

In light of these practical observations concerning the value of leguminous crops as enrichers of the soil, it is not surprising that the earliest researches of agricultural experiment stations deal with an examination of leguminous plants, especially with their nitrogen nutrition. In Europe as well as in America, the history of both federal and state experiment station is intimately connected with studies on the various problems associated with the question of fixation of atmospheric nitrogen by plants. The literature resulting from these researches has been reviewed by Fred, Baldwin and McCoy,[2] who in an effort to examine all important publications on this subject collected a file of over 2,000 references. Access to such a population arouses an irrepressible urge in the student of statistical science to make some sort of classification of the catalogued items. The problem then reduces itself to selection of a basis of classification which will provide the maximum information with respect to the biological properties of the population.

[2] Wisconsin Studies in Science No. 5, 1932. The authors wish to express their appreciation to Dean Baldwin and Professor McCoy for their cooperation in the preparation of this manuscript.

Before discussing the data, it might be well to consider briefly the methods used and to indicate certain limitations in the sample. The publications of a given year were divided into nationalities with respect to *total number* and to *total pages*. By nationality is understood that of the journal publishing the paper rather than the native country of the author, since the latter is frequently difficult to determine. In a large sample, heterogeneous "crossings," *i.e.*, Frenchmen publishing in German journals, should tend to compensate one another. In the case of papers appearing in journals which publish in several languages, *e.g.*, *Zentralblatt für Bakteriologie*, the publication was credited to that nation whose language was used. In the latter case it was necessary to ascertain the nationality of the author of those papers published in English. In order to eliminate, at least in part, the variations which arise from time lag in the date of publication after receipt of the manuscript, the data were averaged for a two-year period.

It might appear to be advantageous and desirable to classify the material according to subject-matter. This plan was rejected when it was found that many publications would fall into several groups with a resulting confusion that would defy analysis. Instead, the predominant topics of investigation of a given period will be discussed briefly in a general way in the text.

Although the authors of the monograph endeavored to collect all extant original contributions to the subject, it is obvious that certain papers were overlooked or eliminated from consideration. These will include: (1) A vast number of popular articles and semi-popular bulletins, the scientific nature and value of which are open to question; (2) papers of recent publication and hence not yet in the "literature," *i.e.*, abstracted or referred to by other authors; (3) papers appearing in obscure journals that are not abstracted; (4) papers with practical value for a given locality and whose circulation is accordingly limited, *e.g.*, station bulletins and reports. Cases three and four will tend to create a bias in favor of the United States, since very rarely would a publication on this subject in the United States fail to be noted in the *Experiment Station Record*.

The Embryonic Period—Before 1886

Production of research articles since 1884 pertinent to the subject of nitrogen fixation by leguminous plants is indicated in Fig. 1. Prior to the middle of the nineteenth century, a few papers had appeared on this subject, notably the studies of Boussingault, Ville and Liebig dealing with whether or not plants in general can utilize the free nitrogen of the air. From 1850 to 1884 this subject received increasing attention, a total of 90 papers appearing during this period. The contributions came from many countries and the rate from any one nation was erratic, hence no attempt was made in this figure to plot the growth prior to 1884.

The data were conflicting, the publications were often polemical in nature, and the question of the ability of plants to fix atmospheric nitrogen remained unsettled. It is interesting to note that in many of these papers the answer to the perplexing problem was shrieking to make itself heard above the din of controversy. *A posteriori* it is easy to see that Ville, Lawes and Gilbert, Boussingault and Atwater all published experiments which might have clarified the muddled situation, had the proper interpretation been forthcoming.

Ville in France claimed that all plants —legumes, grains and grasses—can utilize free nitrogen and convinced a referee board including such distin-

guished scientists as Dumas, the chemist, and Chevreul and Regnault, the physicists, of the truth of his claims. Ville's fellow countryman, Bossingault, likewise presented data from field experiments which had been carried out for 16 years and which seemingly offered strong proof that leguminous plants fixed atmospheric nitrogen. Liebig convinced the majority of investigators, including Boussingault himself, that the observed gains in nitrogen were only apparent and rested on errors in the analyses of the manure added to the fields.

Lawes, Gilbert and Pugh at Rothamsted in England conducted experiments which were masterpieces of technique and concluded that no plant is able to use free nitrogen. Cereals and leguminous plants were grown under glass in sterilized soil and supplied with sterile water and air; their exact control kept out the bacteria necessary for nitrogen fixation by the *Leguminosae.* These workers were cautious enough to suggest that the conditions of their experiments were artificial and abnormal, since field experiments indicated that *Leguminosae* obtained more nitrogen than was present in soil, rain and seed.

Probably closer to the solution of the problem than any of these was Atwater, of Wesleyan University, Middletown, Connecticut. In the early eighties, through "the generosity of Hon. J. W. Alsop, M.D., who, by defraying the larger part of the pecuniary cost and by aid in other ways, has made the investigation practicable," Atwater and his assistant, Woods, made rather extensive experiments with the pea plant. The plants were grown in the greenhouse and in the open in the presence of varying levels of nutrients, including combined nitrogen. The nitrogen balance at the end of the experiments showed conclusively that nitrogen had been acquired from the air in such quantities as to preclude the conclusion that it had been assimilated as ammonia. In spite of the fact "that plants assimilate free nitrogen is contrary to the general belief and the results of the best investigators on the subject," Atwater clung persistently to the belief that leguminous plants could use free nitrogen. In his first report (1884) before the British Association for the Advancement of Science, Atwater offered no explanation for his data; later in the *American Chemical Journal* he attempted to reconcile his findings with those of the "best investigators." Two factors that might have influenced his results and not those of the others were suggested—electricity and microorganisms. Both of these were novelties in science and Atwater appeared to embrace both without favor or prejudice as the possible missing link. In 1886 he again discussed his experiments in the December issue of the *American Chemical Journal,* stating:

> To what extent the attested acquisition of atmospheric nitrogen is a function of plant alone, in how far it may be dependent upon the action of electricity, microbes or other agency induced by the plant, by what species of plants and under what conditions it is accomplished are of course matters for future study. . . .
>
> I am aware of no observed fact to imply that these (ignited sand and nutrient solution) separately or together are able to fix nitrogen by aid of electricity, microorganisms, or any other means. In the present state of our knowledge, therefore the balance of probability seems to decidedly favor the assumption that the plants themselves must be factors in the acquisition of atmospheric nitrogen. . . .
>
> But whatever may be the plants that acquire atmospheric nitrogen, the ways by which they acquire it or the form in which it comes, the fact of its acquisition seems well established.

Atwater clearly recognized the possibility that both plants and bacteria may be factors in the fixation process but was confused by the other alternatives, notably electricity, and thereby missed the solution of the problem. Prophetically he adds:

> And late research leads us to hope that the explanation of the process by which the nitro-

gen is acquired may be found, perhaps in the near future.

The hope had already been realized. In 1883, Hellriegel and Wilfarth, two rather obscure German plant chemists, had begun a series of experiments which were destined to supply the key to the puzzle. Initially they had planned only to study the influence of the quantity of combined nitrogen on the yield of crops, seemingly a somewhat obvious and simple problem. At the end of two years of work, Hellriegel and Wilfarth could enumerate three facts, well established but unexplained. Cereal crops grown in sand cultures, supplied with a nutrient solution complete except for the element nitrogen, grew in proportion to the quantity of combined nitrogen added, but the growth of a leguminous crop apparently was independent of added nitrate. Moreover, chemical analyses demonstrated that the leguminous plant, peas, often showed gains in nitrogen which must have come from a source other than the sand or nutrients; no such gains were observed with the cereals. Finally, the pea plants in the *control* pots, *i.e.,* pots to which no nitrate was added, developed in a most confusing and inconsistent manner. Duplicate pots would be quite at variance with each other; the peas in one would be tall with dark-green foliage, in the other, stunted and yellow.

In a manner not unlike that of the detective in mystery fiction, these two methodical German investigators searched for a clue in the mass of evidence which would lead to a rational explanation of the seemingly irrational data. Four hypotheses, advanced by other workers to explain the differential response of cereals and leguminous plants to nitrogen nutrition, were carefully applied to the data, and each in turn rejected. Elimination of these hypotheses was in the main due to the unexplained vagaries of the control pots; four "beautiful hypotheses were slain by one ugly fact." But what at first appeared to be only a major tragedy of science proved to be in the end the long-sought-for clue. The curious, variable behavior of the peas in the control cultures could be interpreted as the random distribution of some unknown factor, a factor which entered the cultures from the outside and which enabled leguminous plants to fix nitrogen. If this were the case, one would expect the fixation to be unpredictable, since whether or not this factor reached a given culture might well be governed by the laws of chance. To construct an adequate hypothesis on the basis of this idea was the next step toward the solution. Hellriegel knew that the air contained microorganisms, that certain species of microorganisms were able to fix atmospheric nitrogen and that some plants lived symbiotically with lower fungi (mycorrhiza). Reports in the literature had offered strong evidence that the protuberances on the roots of the *Leguminosae,* the nodules, were filled with bacteria. These observations were combined into a simple yet complete explanation of the facts: bacteria from the air fell into the open sand cultures, infected the peas, forming nodules which enabled the plant to use free nitrogen; the bacteria were without effect on the cereal crops. Although this hypothesis brought order into the confused results of previous experiments, publication was delayed until it could be critically tested.

In March, 1886, Hellriegel and Wilfarth began the crucial experiment. In one series, seeds, sand, pots and nutrient solution were carefully sterilized and the sand protected from chance infection by sterile cotton; the second series was identical, except that the pots were deliberately infected with an extract of a rich garden soil; in the third series nothing was sterilized and infection left to chance. This experiment was a complete failure—in their anxiety to eliminate microorganisms a sand was obtained which had been strongly ignited; the ignition had formed an ash so alkaline

that none of the plants grew. The experiment was discarded and a second started in May; Hellriegel's sole comment on what must have been a bitter disappointment was that the duplicate experiment was begun "late, but as the following will show, not too late." Seldom has a critical test given such perfect results. Peas grown in sterilized sand behaved as did the cereals, *viz.,* the growth was dependent on added nitrate, but in the sterilized sand plus soil extract all cultures of peas grew luxuriantly and fixed quantities of free nitrogen. In the non-sterile sand the development of the peas was erratic, as in the former experiments. At harvest the verification was complete; peas grown in the sterilized sand were free of nodules, but those in the sand plus soil extract were covered with the characteristic tubercules. In the non-sterile series only those plants which were tall and thrifty were infected.

Hellriegel appeared before the agricultural experiments section of the Versammlung Deutscher Naturforscher und Aertze in September, 1886, dramatically exhibited typical pots of leguminous plants and cereals and made his report. His discussion of the results was brief, but the demonstration of actual plant cultures met all arguments. Ironically, this meeting in Berlin was presided over by Henry Gilbert of Rothamsted, whose painstaking experiments of thirty years previous were thought to have settled the question, but whose conclusions were now shown to be in error—an error arising from too much care! Undiscouraged, Gilbert returned to England and soon published an account of experiments which are masterpieces of technique and which completely confirmed the findings of Hellriegel and Wilfarth.

The Period of Development (1886–1914)

The discovery of Hellriegel and Wilfarth immediately stimulated research on nitrogen fixation; reference to the figure shows that a real bull market resulted during the next few years. Scientists of many nations vied with one another in turning out copy at a terrific pace. Germany dominated the field, but France was also prolific; the British Empire produced at a more conservative rate and America made modest contributions through the efforts of Atwater and collaborators. Many of the papers during this period of accelerated development were less than ten pages in length and were often published in series. An author would publish six or seven articles bearing the same title in a single volume of a journal, each article dealing with a detail of one major experiment. It is probable that the modern editor would not accept such "squibs," at least on this subject, and this must be kept in mind when comparing the output during this Golden Age of production with later periods. Subject-matter of most of the contributions is monotonously similar—the experiments of Hellriegel and Wilfarth have been confirmed. It is a tribute to the genius and careful work of these two men that few dissenting votes are noted among the many checks on their work.

Interest in the question of whether or not all plants can use free nitrogen was revived, and during the period 1890–1895 the last mass attack was made on this question. The old experiments were repeated and new ones devised, but the results with plants other than members of the *Leguminosae* were uniformly negative. Since 1900 investigations on this subject have dwindled to the sporadic efforts of the more intrepid workers.

One important contribution made during this period must not be overlooked, *viz.,* the isolation in pure culture of the causal organism. Hellriegel and Wilfarth were plant chemists and were uninterested in the finer points of the biology inherent in their work. They employed for inoculation crude culture

of soil or extracts of soil. In 1888 Beijerinck isolated pure cultures of the organism from the nodules of various leguminous plants and laid the foundations for the extensive bacteriological studies necessary for final solution of the problem.

About 1895 the zeal to verify the experiments of Hellriegel and Wilfarth had largely subsided and the rate of production fell off decidedly. Simultaneously the content of the papers changed; editors probably began to reject what an unkind critic might term "pot-boilers," and attack on some of the more complex features of the symbiosis became necessary. With the formulation of the complicated aspects of the problem, there was a sudden loss of interest which caused a sharp dip in the curve of production. Nevertheless, during the period of this "low," some of the most suggestive and provocative contributions were made, notably by the Germans, Frank, Nobbe and Hiltner, and by the Hollander, Beijerinck. A few of the questions raised by these investigators, many of which have not received final solution after 40 years of research, include:

(1) Does one species of bacteria attack all species of *Leguminosae,* or does each species of plant require a special type of bacteria?

(2) Are the bacteria capable of fixing nitrogen apart from the proper host plant?

(3) What is the explanation of strain variation, *i.e.,* why does one strain of the organism benefit the plant, whereas another strain of the same species proves non-beneficial?

(4) What is the best manner to apply artificial inoculation to crops? Under what conditions should artificial inoculation be used?

(5) What is the chemistry of the process?

(6) What members of the *Leguminosae* are especially suited for use as green manures? How should these be handled?

(7) What is the order of magnitude of nitrogen returned to field by various leguminous crops when used as a green manure? When the crop is removed?

From 1895 until 1915 there is a gradual but steady increase in the rate of production of research papers. In these 20 years the influence of German science is manifest; without a doubt, the Germans were the leaders in this field with respect to both quality and quantity of contributions. At the beginning of the century the number of papers by American investigators rose rapidly and soon were threatening the German dominance. Part of this was due to the efforts of Moore at the U. S. Department of Agriculture, who succeeded in popularizing this field of research among the investigators at experiment stations. Likewise the expansion of experiment stations in numerous states aided in swelling the total of publications from the United States. A large number of the American contributions at this time were in the form of station bulletins and dealt primarily with practical problems, *e.g.,* the type of leguminous plants to use in a given locality or with the benefits of artificial inoculation. While the publications from the United States increased rapidly, those from the British Empire exhibited a more restrained development and those from France declined. It is noteworthy that research on this problem in countries other than the "Big Four" was definitely established during the period from 1895 to 1915.

Approaching Maturity (1915—)

Even before the world war, there was evidence that the United States was to assume leadership in the production of research concerned with nitrogen fixation by the *Leguminosae.* With the start of the conflict this occurred. Among the European nations the quantity of research fell off sharply during the period from 1914 to 1919, while an actual expansion took place in the United States. The explanation of the increase in the productivity of America during the war probably rests on the fact that food production for man and beast was the feature of our participation. Research in the field under con-

sideration accordingly would be stimulated by the national crisis; the increase does not imply non-participation in war activities by the American scientists as might be superficially inferred.

One of the most important of the practical contributions made during this period was the development of reliable methods for supplying pure cultures of the bacteria for artificial inoculation of leguminous seed. Such cultures made unnecessary the use of the laborious and haphazard soil transfer method previously used to provide the proper organisms. The majority of previous attempts to furnish pure cultures had proved disappointing and frequently disastrous mainly because lurid, exaggerated claims made to sell the cultures were substituted for scientific control in their production. Research at several experiment stations, notably the Soil Bureau at the U. S. Department of Agriculture, Wisconsin and Cornell, resulted in the development of a technique which insured successful production of dependable cultures of the various legume bacteria. Because of the previous exploitation by unscrupulous purveyors of "inoculum," farmers viewed with skepticism if not suspicion the new product. Gradually through demonstration and education they were not only convinced of the advantages of artificial inoculation for leguminous crops but also appreciated the limits of the benefits to be expected under various conditions.

At the termination of the war, the contributions from the United States showed a definite decrease, a reaction common to many of the wartime industries. This decrease continued into the early twenties, but at the same time research was revived in Europe so that the curve of production for the entire world began to rise. About the period from 1922 to 1923 the rate of production climbed in all countries, but especially in the States. The upturn in this country was so precipitous that about 1928 there is evident a sharp peak in the curve of production for the United States, a peak that carried the curve for the entire world into dizzy heights. This period of pronounced inflation is rather disconcerting to one endeavoring to find law and order in the growth of a literature, but it is believed the following explanation accounts for the sensational rise and subsequent fall.

In all countries, a political philosophy of self-sufficiency gained varying degrees of support. This political ideal of ability to provide all necessities within the national border would certainly focus attention on the fact that an intensive agriculture depends on a supply of cheap nitrogen. As an organism seeks to make the correct response to a changed environment, so would the state seek methods to furnish this requirement for a nationalistic existence. Under these circumstances impetus to research concerned with fixation of atmospheric nitrogen by biological or artificial means would be expected. Another factor that probably contributed to the rapid development during the twenties was the preeminent position of all natural sciences. Scientific achievements of the war had so appealed to the mass mind that they turned hopefully to the scientists for the means to rescue them from the complex political, social and economical difficulties which ushered in peace. Popular support for all research was to be had even in those countries whose financial status was precarious. Later, disappointed with scientific leadership, the mood changed and scientific programs suffered deflation.

In America the factor of economic prosperity, absent in other nations, undoubtedly played a rôle. One result of this prosperity was an expansion in the budgets of institutions devoted to research—it is probable that many experiment stations and universities undertook work in fields that ordinarily would be classed as "marginal." With the onset

of the depression came tightened purse-strings and administrative frowns on research concerned with production aspects of national economy. The effect on the literature curve of nitrogen fixation by leguminous plants is unmistakable; the similarity of the curve with that of 50 representative stocks on the New York exchange for the period from 1923 to 1933 is readily apparent.

Although the caliber of much of the work reported during the period of prosperity must await future evaluation, the stimulus to production resulted in at least one desirable feature, *viz.*, the broadening of research programs. The practical problems which dominated the war period were stressed comparatively less and some of the more fundamental aspects were attacked. These included a complete reinvestigation of the strain variation problem and of nitrogen fixation by the bacteria apart from the host plant; new fields tentatively explored were detailed studies on the biology of the organism and on the biochemistry of the fixation process.

As an example of the manner in which theoretical studies often lead to conclusions of great practical significance may be cited the progress of the so-called "strain variation" problem. About 1920, work was started at the Wisconsin experiment station on a fundamental study of physiological differences in strains of the organisms isolated from different plants of the same cross-inoculation group. The research eventually demonstrated that mere inoculation with organisms of the proper group did not insure benefit to the host plant, since ability of different strains to fix nitrogen after invasion of the plant varied widely, some strains being definitely parasitic on the plant. This fact provides added reason for the use of pure cultures of known efficiency in order to insure maximum returns and at the same time emphasizes the need for exact control in the distribution of artificial inoculation.

The discussion has been restricted to *number* of papers which may not be the best measure of production. Because of differences in editorial policies or in methods of publication, the size of papers in various countries may vary considerably, hence the number of papers per year may be a fictitious criterion of research capacity. A plot was made of the mean size of papers since 1883; the data showed that on the average 60 per cent. of the papers are less than 10 pages in length, 20 per cent. are from 10 to 25 pages; from 10 to 15 per cent. are from 25 to 50, and the remainder are over 50 pages. The percentages did not vary considerably over a period of 50 years, although a preponderance of small papers featured production during the decade from 1885 to 1895. Since many of these were from Germany, a plot similar to Fig. 1 was made in which the output in number of pages per nationality was used as the ordinate. The resulting graph was little different from that given in Fig. 1; the peak during the period from 1885 to 1895 was not quite so pronounced and the German dominance from 1885 to 1910 was less marked.

The Extended Population Curve

The treatment so far has been a more or less empirical description of the growth of a body of literature together with observations regarding possible forces which influenced the growth. It is of interest to determine whether or not a quantitative expression of this development can be obtained. The mathematical curve that might be expected to describe the growth would be a representative of the logistic, or population, family. These curves describe phenomena which behave in the following manner: (1) The rate of production at a given time is proportional to total production (or change in rate of production is proportional to the latter); (2)

there is some upper limit to the rate of production.

A priori these considerations would appear to apply to the development of the literature of a given research, *i.e.*, the production during a given year should be roughly proportional to the total produced, but a limited rate of production would be eventually reached. The first of these follows from the fact that the more publications which appear, the larger is the audience that is likely to become interested in the problem; likewise the tendency to follow the crowd is evident, even among scientists. The second condition, *i.e.*, the attainment of a limit, takes place when the field becomes saturated; new contributors are no longer readily attracted because of either dearth of problems or difficulties in publication.

Mathematically[2] these conditions are expressed:

$$\frac{d^2N}{dt^2}=K\frac{dN}{dt}\left(A-\frac{dN}{dt}\right) \text{ which integrates into}$$

$$\frac{dN}{dt}=A-\frac{A\,(A-\alpha)}{A-\alpha+\alpha\, e^{kat}}$$

A—limiting rate of production
N—total number at time t
α—constant representing production at $t=0$
K—proportionality constant

Tamiya[2] has shown that the literature devoted to research on the fungi *Aspergillus* follows quite closely a curve of this type.

The data of Fig. 1 were replotted and by trial and error the constants evaluated for the arbitrary origin t equals 0 at 1860 and α equals unity. Since even a casual inspection shows that in no case will the fit of the points be close to a smooth logistic curve, no attempt was made to secure the "best" curve in the least square sense. The population curve that appears to best fit the data is shown in Fig. 2. It is apparent from a study of this figure that the points follow the indicated curve in a general

[2] *Botanical Magazine*, 45: No. 530, 1931.

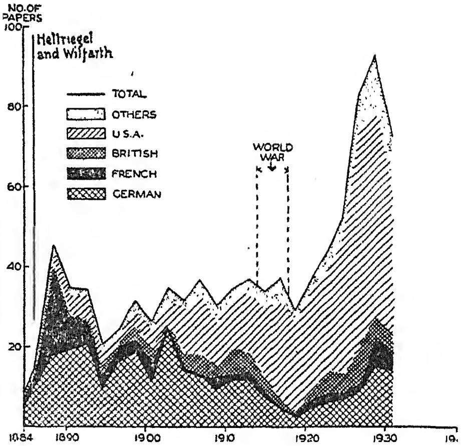

FIG. 1. THE DISTRIBUTION OF PUBLICATIONS ON NITROGEN FIXATION BY *Leguminosae* SINCE 1884.

way, but that the fit leaves much to be desired. The worst departures from "theory" occur at: (1) Following Hellriegel and Wilfarth experiment; (2) the world war; (3) 1928–1929. The explanation of these peaks and valleys has been already indicated.

It appears that the subject of nitrogen fixation by leguminous plants is so intimately connected with the business of living that the research in this field is rather sensitive to upheavals in the political and economical world. The subject-matter is so closely intertwined with the larger problem of production that support of research at a given period is a function of current economic

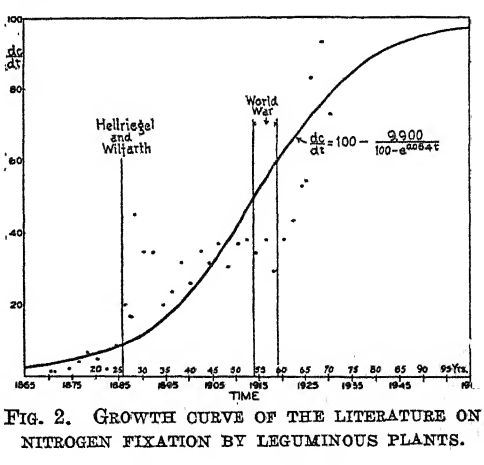

FIG. 2. GROWTH CURVE OF THE LITERATURE ON NITROGEN FIXATION BY LEGUMINOUS PLANTS.

or political theories as well as the "natural" inclination of a given scientist to work in this field. In the theoretical development of the equation it was postulated that this inclination was conditioned only by magnitude of previous work and by proximity to the ultimate limit. Because of the effect of superimposition of external on the internal factors governing development, the growth appears to be more lawless than is really the case.

On the other hand, the literature of research with *Aspergillus,* an organism used mainly in physiological and anatomical studies, reflects academic interest primarily and is much less responsive to affairs of the world outside the laboratory. In such a case the fit of the observed with the "theoretical" might be fairly close, as was actually found.

Another influence which has caused occasional departures from the smooth curve in the case of the literature of nitrogen fixation is the ability of certain leaders to stimulate research. Attention has been called to Hellriegel and Wilfarth in Germany and to Atwater and later Moore in the United States. In recent years Virtanen of Finland has done much to accelerate the research in eastern Europe, with the result that the work of *Others* has become an appreciable part of the total. However, the impetus given to research in the Union of Socialist Soviet Republics since the revolution, a political event, has also been a factor in increasing the output of the unclassified nations.

In conclusion, it appears from the "smoothed" data that the research student of the future can look forward to an annual production of approximately 100 publications a year in this field. This limit of production seems likely to occur about 1965 to 1970. Likewise, the total number of pages to be mastered each year will be from 1,500 to 1,600 before the harassed student may look for relief from an ever-increasing annual load.

It is highly desirable to apply proper correction factors to the foregoing estimates in order to compensate for the apparent powerful influences on the research exerted by wars, depressions, revolutions and individual leadership. Until the effect of the external environment can be mathematically expressed in our equation of growth, at least as a first approximation, predictions based on a theoretical curve may or may not be more reliable than those found in a daily racing form.

WILLIAM HENRY WELCH, SCIENTIST AND HUMANIST

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In my life as a doctor I have met three men and only three who exercised a personal influence of such magnitude that they dominated the medicine of their time. These three men were Osler, Billings and Welch. Differing in mental endowment and in ancestral background, each had a personality that separated him from his fellow men. Osler typified what is still comparatively rare in America, the scholar in medicine. To him is largely due the growing interest in the humanities among medical men, although that is not his only claim to fame. He pointed out in his writings and in his teaching the value as well as the charm of clinical or bedside study. Throughout the land his younger contemporaries and his successors have striven to emulate him as a teacher, to be second Oslers. Frank Billings was not a profound scholar. The humanities attracted him but little. With the magnificent frame of a pioneer in a pioneer region he had time mainly for the practical things of life and left the ornamental to others. Forthright, clear-thinking, generous, a first-rate doctor and far-visioned educator and organizer, he acquired an extraordinary influence through the length and breadth of the land. His direct personal influence on the host of young men who came within the range of his personality made devoted disciples of them. They became Billings men, keen clinicians, able diagnosticians and safe counselors in the crises of life.

Welch did not come from a raw and sparsely settled country, like Osler, nor from the striving and restless Middle West, like Billings; he was the product of the best stock in an old and long-settled community, a stock that has impressed itself upon our nation as no other. In the little town of Norfolk, Connecticut, and in the immediate neighborhood the Welches had lived for generations, mainly following the profession of medicine. He himself was the tenth Dr. Welch in the family. His father, William Wickham Welch, a beloved practitioner, was to the old citizens of Norfolk the most famous of the entire Welch line. To him his son William erected a fountain with the beautiful legend, "Fons sum solati, talis et ipse fuit—I am the Fountain of Comfort as He was Himself." From such an ancestry, in which culture and self-assurance had been at home for generations, Welch inherited the personal dignity and the charm of bearing that were his striking possession. He was at home in any circle—the great men of capital and business, statesmen, the highest military officers, even Presidents were proud to be his friends. His figure was not a commanding one—he was short, stocky, thick-necked and obese; nevertheless, he was the focal point in any gathering, medical or nonmedical.

Welch had the gift of friendship in a rare degree. Courteous, kindly, tolerant, not given to sarcasm, free from the superiority complex, to which more than any one else he was entitled, he had no enemies. In some men that might signify a weak character, one unwilling to assert itself. That was not true of Welch. At scientific meetings he never hesitated to criticize a speaker with whom he did not agree, but he always did it with such fine tact, with such good nature that he did not make an enemy

of the man he criticized. At the banquet given in his honor in 1910, Councilman said, "Has any man ever heard Welch speak ill of his neighbor?"

Welch was born in 1850 and was sent to Yale College at the early age of sixteen. At that time the classics still dominated education, so that, together with the sciences, he acquired a knowledge of Latin and Greek which he increased by teaching these languages for a year after graduation. It can perhaps not be proved, but personally I feel that the type of education he received—largely humanistic—made it possible for him to become the all-round scholar that he was. I am not reconciled, and I doubt whether Welch was reconciled, to the elimination of the so-called dead languages from the college curriculum. In truth, they are not really dead, for they are still the sources of the language of science. To Welch Latin and Greek were more than two more languages. They were the key to two more civilizations. It is, I agree, no longer necessary to give them the main place in the college curriculum. Even so sturdy a defender of Greek as DuBois Reymond, after having first pleaded for Greek as a requirement for a medical education, late in life cried out, "more conic sections and less Greek."

After teaching Latin and Greek for a year Welch entered the College of Physicians and Surgeons in New York City. With prophetic vision he soon saw the value and need of chemistry, and this induced him to return to New Haven for advanced studies in that and kindred fields. He took courses both in the Sheffield Scientific School and in the Yale Medical School and was greatly stimulated by Professor Oscar Allen and by George Frederick Barker, afterwards professor of physics in the University of Pennsylvania. Welch became deeply interested in the new chemical theories propounded by Kekulé, the originator of the benzol ring concept of organic compounds. Within a year he had mastered the exciting theories in the original German. On completing these important studies Welch in 1872 reentered the College of Physicians and Surgeons, where the course of instruction had recently been extended from two terms of four months each to three terms of five months each. Through the influence of Francis Delafield, one of the founders of pathology in this country, Welch began even as an undergraduate to make autopsies at Bellevue Hospital and to study morbid changes with the microscope. He had won the Seguin Prize, a Varick microscope, for the best report of the clinical and didactic lectures of Seguin, famous professor of nervous diseases. His graduation thesis on goiter not only won for him the first prize, but also in its preparation taught him the use and value of medical bibliography.

Six months before graduation Welch was already acting as intern in Bellevue Hospital. Here he came in contact with a brilliant group of men such as Francis Delafield, E. G. Janeway and Abraham Jacobi. A number of others also influenced him at this formative period—Charles McBurney, Alonzo Clark, Austin Flint and Alfred Loomis. At the end of a year and a half's internship Welch, accompanied by his friend, Frederick S. Dennis, set sail for Europe. For him and for American medicine this proved to be a momentous step. The Civil War had interrupted the migration to Europe, which in the earlier decades of the century had taken some of the best men to Paris, London and Edinburgh. Germany was just beginning the wonderful work in medicine, in chemistry, in biology that eventually made her the Mecca for eager learners from all parts of the world, a position she lost with other intangible things as the result of the great war. Strassburg, which the Germans had raised to a university of highest rank, was Welch's

first stopping place. Here he worked with Waldeyer in histology, with Hoppe-Seyler and Baumaun in biochemistry, virtually a new science at that time, and with von Recklinghausen in pathology. After a short stay at Strassburg he went to Leipzig, where he found many other foreigners in the famous physiological laboratory of Carl Ludwig. Magendie, Charles Bell, Johannes Müller, Claude Bernard in the earlier part of the century had blazed the way that was now being followed with brilliant results in physiology by Helmholtz, by DuBois Reymond and by Ludwig. Welch discussed with Ludwig the advisability of working with the mighty Virchow,[1] but Ludwig, who was not completely won over to the cell-doctrine, suggested that Welch instead go to the youthful Julius Cohnheim in Breslau, which was a happy choice and proved of decided importance for Welch's future. As we shall see later, it was Cohnheim's recommendation that largely influenced President Gilman of Johns Hopkins University to offer the chair of pathology in the new medical school to Welch.

In Cohnheim's laboratory Welch was associated with Karl Weigert, to whom pathology owes many important discoveries, including valuable methods of staining tissue elements in preparation for microscopic study. Others in Cohnheim's remarkable institute were Ehrlich, Lassar, Neisser and Salomonson. The atmosphere was electric. Every one was pursuing some individual problem assigned to him by the master. That of Welch was the ascertaining of the causes of acute general edema of the lungs. The result appeared in an essay that is still a classic; it was written by Welch in German and printed in *Virchow's Archiv* essentially as Welch had prepared it. A number of years ago I had occasion to read this article. At that time I thought that some one had translated it from Welch's English into good German. It did not seem possible that any one not a native or long familiar with the German tongue could have written it in the vernacular.

Summer vacations in Europe were used by Welch for walking tours. During one short holiday he walked 210 miles in Switzerland. That was good exercise for a man inclined to be stout and gouty.

While at Breslau Welch had a memorable experience that helped to shape his subsequent career. He was present when Robert Koch arrived to show Cohnheim his bacteriologic discoveries, which consisted at that time chiefly in isolating and growing microorganisms—it was still five years before the discovery of the tubercle bacillus.

On Cohnheim's advice Welch went to Prague to visit Edwin Klebs, who was then engaged in his fruitful studies on acute endocarditis and diphtheria. From Prague he passed on to Vienna. He was disappointed in the opportunities he found there for the object he had in view, the study of embryology. Nevertheless, his stay there in the fall of 1877 proved invaluable. He entered with zest into the cultural activities, into the music and art life of the gay Austrian capital, the gayest then, as it is the saddest now. After the winter in Vienna he returned to Strassburg to continue his studies with von Recklinghausen, who was one of the leading representatives of the Virchow school of pathologists. As a suitable *Arbeit* von Recklinghausen assigned to Welch the study of the inflammation of the frog's cornea, induced by various caustic chemical agents. This study was intended to determine the origin of the pus cells, a question which at the time, the late 70's, was the cause of intense and bitter controversy between the Virchow and the Cohnheim schools. Was the pus cell

[1] Nevertheless, Welch's admiration for Virchow was unlimited. He recognized in him the pioneer, the master—*il maestro di color che sanno*—and put him on a pedestal with Vesalius and Harvey.

an emigrated leukocyte of the blood, as Cohnheim contended, or was it the product of the multiplication of the fixed tissue cells? Although Welch's experiments seemed to favor the latter, or Virchow theory, he was not willing to draw any far-reaching conclusions on the basis of his own researches. Indeed, it required many years of further observation and experimentation before the final proof was brought that connective tissue cells under the influence of chemical stimulants become motile and multiply so as to surround and to invade the chemically altered area.

His work at Strassburg being completed, Welch spent a few delightful days in Paris and then paid a second visit to London. Here he found the medical world in a fever of excitement over Joseph Lister's bold surgical exploit of opening the knee joint. We of to-day can hardly understand this excitement, unless we remember that antisepsis was still in its infancy.

His Wanderjahre being ended, Welch was ready to turn his steps homeward. He had studied under some of the best masters in the world. The phrase that I have just used is rarely heard in this country. We would say a man went to Pennsylvania or Harvard, to Yale, to Johns Hopkins, but in Germany a man studied under this or that professor. The distinction is significant. When our universities become real universities in fact as well as in name, then a man will study under such and such a master rather than at such and such a place.

Welch was back in New York in the spring of 1878, trying to see whether any one prepared as he was could find work in that great city. As he needed to earn a livelihood he was for a time undecided whether to stay in New York or whether to join his aging father in the practice of medicine at Norfolk. At that critical moment he fortunately fell in with Dr. Golthwaite, a well-known quiz master. The quiz was, as Welch long afterwards put it, a life-saver. But he abandoned the work after three years because he felt that it injured both the students and himself. The identical conclusion was reached by many of us in Philadelphia who as students and as teachers had experience with the quiz system.

During this probationary period in New York a little practice came to him from his old teacher Alonzo Clark, but it did not divert him from his main objective, the study and teaching of pathology. His Alma Mater offered him a lectureship in pathology, but as it did not provide a laboratory he with some heartache accepted the offer of the rival school, Bellevue Hospital Medical College, where three small rooms for the purposes of a laboratory were assigned to him. This constitutes in a sense an historic event, for it was the first recognition in this country of pathology as an independent discipline. Soon, however, the College of Physicians and Surgeons realized the need of a similar chair and offered it to Welch. He declined, feeling that he could not desert his friends at Bellevue and suggested T. Mitchell Prudden for the place. With the latter's prompt appointment pathology was definitely established as a branch of medical education coequal in importance with anatomy and physiology. To Virchow belongs the credit of having done this originally, for it was he who raised pathology to a definite science.

Welch's work in New York in teaching and investigation soon attracted attention. One day a man came into the room while Welch was lecturing on syphilis and without making himself known remained throughout the teaching period. The visit had momentous consequences, for the silent visitor, John S. Billings, had come to select a man to fill the chair of pathology at the new

hospital and the contemplated medical school in Baltimore. President Gilman, one of the greatest educators in the history of this country and one of the best judges of human nature, planned to create a medical school on new principles. Welch, recommended not only by Billings but also by the influential Julius Cohnheim, received the first appointment to the faculty. In that manner a pathologist became the head and real founder of the Johns Hopkins Medical School. Realizing the growing importance of bacteriology and his own need of knowing it in order to fit himself for his new position, Welch returned to Germany in the summer of 1884. After a year of intensive study he came back thoroughly at home in the newer bacteriologic methods of Robert Koch. He began his work at Johns Hopkins Hospital in 1885, several years before the medical school was opened. His energy and magnetism drew to him a group of men whose names are now household words, Councilman, Abbott, Nuttall, Halsted and later Flexner, Barker, Mall and MacCallum.

In the choice of the major faculty of the Johns Hopkins Medical School Welch exercised a paramount influence. It was through him that Halsted was called from New York and Osler and Kelly from Philadelphia. What that remarkable quartet meant for medicine in America I need not discuss. Its influence continues to this day after all but one of the four have died.

Welch was the dominant figure in the new medical school and rapidly extended its reputation far beyond the confines of Baltimore. Everywhere, in all medical schools, Welch's personality began to be felt. His influence upon medical education was manifold and in its totality was unquestionably greater than that of any other man in the history of this country. It is not easy to analyze it, for it was all-pervading and touched on many fields. One outstanding phase was the making of pathology a required fundamental branch in medical teaching. It was natural that in such an undertaking he should emphasize the value of the laboratory. As a result of this emphasis practically every medical school of importance and even many hospitals established pathological laboratories. Some were for research as well. What this meant for the progress of medical science in this country can not be over-estimated. Compared with Germany, the spirit of research was but poorly developed in this country when Welch established his laboratory in Baltimore.[2] He attracted to himself a group of eager young men who advanced so rapidly in reputation that they were called upon to fill chairs in other medical schools. In that way Welch's influence reached out over the length and breadth of the land. Councilman went to Harvard, Flexner to Pennsylvania, Lafleur to Montreal.

One reason for Welch's remarkable influence was that he better than any one else of his time was aware of the trend of medical education. With unparalleled vision, he sensed instinctively the direction in which medicine ought to go in order to progress, and thus it was that in time he became general educational consultant to medical schools, which rarely adopted a new idea or filled professorial chairs without seeking his advice. Welch was the foremost champion in the medical profession of the so-called full-time system of teaching. One may differ about the wisdom of full-time clinical chairs, at least on the plan originally conceived, but it can not be denied that the academic type of medical teaching is rapidly extending.

[2] A distinguished professor of physiology in a German university once said to Welch, "When America does wake up to the necessity of these things (medical laboratories) then let Europe look to its laurels."

In line with Welch's work for medical education were his efforts in promoting the founding of great research institutions, in particular the Rockefeller Foundation and the Rockefeller Institute, whose benefactions very nearly reconcile one to the accumulations of great wealth in single hands.

A large share of credit must also be given to him for the phenomenal physical improvement in medical schools, which until the early nineties for the most part were but poorly equipped. In 1890–91 there were only five endowed chairs in medical colleges and not a single one of these south or west of Philadelphia. On the other hand, there were 171 endowed chairs of theology, many of these being in the West and South. In 1892 the productive funds in the hands of the medical schools were $611,214, for theological schools $17,599,979. While it would be an exaggeration to say that the reversal of this relationship now obtaining was chiefly due to Welch, his powerful far-flung influence was always exercised in the direction of the physical and pedagogic improvement of medical schools.

As commissioner of health of Maryland, a position he held for many years, Welch set a standard for similar officials in other states; indeed, in all great events of national and state action for public health Welch was the man to whom every one turned for advice both in formulating plans and in selecting personnel. He laid down the lines of action in the great campaign against tuberculosis in this country, and they have been followed throughout the world.

Upon Philadelphia medicine Welch's influence was far greater than is generally known. The Phipps Institute, to whose board of trustees he belonged from the beginning, depended upon him for wise counsel and stimulus. He was consulted upon faculty appointments in the medical schools and upon other matters of educational policy. At the opening of the William Pepper Clinical Laboratory Welch delivered the principal address, which was a masterpiece of historical study of the origin and growth of laboratories.

When Welch reached the age of 66 he resigned his professorship of bacteriology at Johns Hopkins University, not, however, to seek the *otium cum dignitate* to which he was so well entitled; on the contrary, he took upon himself the directorship of the School of Hygiene and Public Health, a position he filled with undiminished ability for ten years. At the ripe age of 76 his friends may have expected that he would decide to retire, but Welch was not the man to rust out. Instead of seeking a life of leisure he began a work which in the future may prove almost as significant for American medicine as anything he did in his life. Supported by generous benefactors he created out of nothing an Institute of Medical History and the wonderful library bearing his name. After he was appointed to the new position he spent two years abroad gathering rare books in all parts of Europe. His unequaled bibliographic knowledge made it possible for him to collect a significant library such as was never collected before in so short a time. The institute, modeled after the famous Leipzig Institute of Professor Sudhoff, is destined under Welch's successor, Dr. Henry E. Sigerist, to play an important rôle in the cultural life of America.

The appointment of Welch to the directorship of the Institute of Medical History was not a mere gesture to a deserving man but a proper tribute to one who knew the history of medicine as well as any man in the field. William Osler once said, adding to a phrase of Oliver Wendell Holmes, "In addition to a three-story intellect Welch has an attic on top." In that attic was stored

a vast amount of cultural knowledge. And what was as remarkable as the contents of his multi-storied brain was the fact that on the spur of the moment he could call upon his memory for details that often gave the impression of careful, lengthy preparation. His memory was truly colossal. He could lecture for an hour or more on historical subjects without making a mistake in dates or sequence. I heard him give the first William Wood Gerhard address before the Pathological Society of Philadelphia. It was, appropriately to the occasion, on the history of typhoid fever. Without notes he began at the beginning, went through the early nineteenth century to Gerhard and then down to modern times without an error and without halting for a word. It was a phenomenal performance that no one present can ever forget.

When Welch reached his eightieth birthday a celebration of truly cosmic proportions took place. In Washington President Hoover attended, and speaking to the 1,600 assembled guests he called Dr. Welch "our greatest statesman in the field of public health." Nearly all large cities of the world held simultaneous celebrations. Welch's address on this occasion was a model of modesty and charm. One of the speakers said, "Dr. Welch waded knee-deep in honors unsought and aroused no shadow of envy or enmity on the way." To the truth of this all who knew Welch personally can testify. No man in medicine was ever so deep in the hearts of his contemporaries.

Welch's enormous influence upon his generation, indeed upon two generations, was due to a combination of gifts. First and foremost was that of good health, with its accompaniment of zeal and vigor, and the second curiosity; curiosity that was not satiated by the triumphs of medicine but extended to literature, to art and to music. His interest in the intangible things that we call the humanities kept pace with his scientific interest. With the scholarship of an Erasmus, the integrity and tolerance of a Contarini, the scientific zeal of a Virchow, we may, I believe, call him the finest exponent of humanism in the history of medicine.

Dr. Welch left no children in the flesh, a disappointment to the eugenist, but no man in the history of American medicine has left a larger number of spiritual offspring, a form of immortality, beyond theology and dogma, reserved only for the greatest of men.

If now, in conclusion, we place William H. Welch before our mental eye to see why he had such a colossal influence upon men and events, we find that he was an all-around personality—not only a doctor, not only a scientist, not only a historian, not only an educator, not only a scholar in literature and languages—he was all these at one and the same time.

Nature unfortunately is parsimonious in such men.

FOOD PROCESSING AND HUMAN WELFARE

By Dr. MARION DEYOE SWEETMAN

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In times of severe economic stresses and social tensions, the laboratory scientist has often disclaimed responsibility for these difficulties. He denies that his discoveries and inventions have produced any net increase in cultural maladjustments or, admitting that maladjustment has followed from application of his research, contends that inadequate social, economic and political leadership are at fault. Neither alibi survives the critical analysis given by Baldwin in a recent issue of THE SCIENTIFIC MONTHLY of the causes of technological unemployment. Natural scientists tend to minimize the complexity of social changes and consequently have a limited conception of the less immediate results of their contributions to human knowledge. Perhaps it would be a wholesome experience for every researcher to take time and thought to judge the welfare value of applications of the discoveries in his field. Such a belief has led to the following attempt to evaluate modern food processing.

It is neither necessary for us to wait upon years of experimentation nor to collect more records of the consequences of dietary habits to trace or predict some results of any dietary change with considerable accuracy. Almost within the bounds of this century, bacteriology, physiology and biochemistry have placed in the hands of the nutritionist exact and objective standards for judging the welfare value of foods. To evaluate any form of processing he has but to ask the following five questions, knowing that techniques for their answer lie at hand:

(1) Has an alteration in the nutritive value of the food been such that its use is not likely to render the average diet less well balanced?
(2) Has the product been altered significantly in digestibility?
(3) Is it equal to other forms of the same foods or similar foods in palatability?
(4) Is it wholesome, that is, free from harmful organisms and substances?
(5) Is it economical in terms of money, labor, fuel requirements and equivalent values in other forms?

Rating by such standards does not condemn all food processing. Scientific evaluations do not compel nutritionists to join the raw or the natural food evangelists. There is no sound reason for assuming that any combination of natural food materials, raw or cooked, will produce the best possible nutrition of any group of individuals under all environmental conditions. The only food designed solely for that purpose is milk, and it is now known that even the human product does not exclusively meet the infant's requirements for but a small fraction of the nursing period. In northern climates it must early be supplemented by such an "unnatural" addition as cod-liver oil if bone development is to proceed normally. No matter how teleological one may be in his attitude toward nature, nor how impressed he is by racial customs which seem to have had survival value, he must admit that nature's criterion of either survival or welfare is hardly acceptable to the modern human as an individual. Her chief concern is with racial continuity. Instead of being content with physical and mental vigor that suffice to meet biological needs and that persist through the reproductive period and such additional years as are of survival value to the children, individual man strives for more years of life

and extension of vitality for their enjoyment.

The golden age of human nutritional welfare, then, is not to be sought in the past, when foods were more or less unaltered plant and animal materials. It lies in the future, when man shall have learned to alter this part of his environment to attain as nearly as possible optimum health and vitality in any part of the earth he chooses to inhabit.

Furthermore, there is no validity in the assumption that household food processing is essentially superior to factory food processing. The nutritionist does not believe that dietetic welfare can be improved only by reinstatement of the domestic kitchen as woman's proper sphere, whether this is brought about by the coercion of a Mussolini or a Hitler, or by the persuasion of a Borsodi. Scientific large-scale techniques may be expected to improve nutritive quality, digestibility, sanitary quality and even palatability of our food, and result in much saving of household labor at a comparatively low cost. The employment of expert technicians, appropriate machines and controlled conditions might produce foods of such uniformly high quality when judged by all standards that the average household would find it neither desirable nor possible to compete in much of the actual processing.

In fact, even as it exists to-day, commercial food processing must be given much credit for human welfare. Without such processes as cold storage, pasteurization and evaporation it would perhaps be impossible to insure as much as the present inadequate consumption of milk for the population as a whole. If one food were to be selected for greatest contribution to maintenance of nutrition at as high a level during the depression as has been possible, probably nutritionists would agree that the honor should be given to evaporated milk. The equivalent of fresh milk in all reliable essentials, more certain to be wholesome than average fresh milk, its substitution for the latter in adequate dietaries at minimum cost cuts the grocery bill for an average family $5.00 per month. The re-enforcement of factory-made ice cream, cheese and bread with added milk solids in the form of skim milk powder is a practice which salvages important and often inadequately supplied essentials of human nutrition that should be duplicated in the household as soon as the skim milk powder becomes available in retail units. Modern canning has been rated by some as the greatest of scientific discoveries. Certainly commercial canning of fruits and vegetables gives products which, although they may not rival the fresh in palatability, increase the chance that the average dietary will be properly balanced at all seasons. We have had a few examples of the commercial manufacture of scientifically supplemented foods, for example, iodized salt, irradiated cereals and milk, which have been or may be rapidly adopted by large numbers with improvement in nutritional status. Such a list is by no means complete but is sufficient to demonstrate that, as it exists, the food-manufacturing industry must be given credit for some contributions to nutritional welfare.

Furthermore, commercial food processing has already created much leisure for the housewife—and the average home-keeping woman still works more hours per week than her dinner-pail-carrying husband. Feeding the family requires more time than any other single household function, from 3½ to 3¾ hours per day in rural districts, somewhat less in towns. The conspicuous waste of leisure by some housewives in socially useless activities should not blind us to the value of time freed from the mechanics of housekeeping by the modern food factory when it is employed in more careful child training, in enriching the social life of the family and in socially

constructive community activities, as well as in creating a more satisfying personal life for the housewife herself.

The removal of much food preparation from the household has undoubtedly made contributions to social welfare and personal satisfaction, though there may be some question as to whether the balancing of benefits against deficits would show a net gain. As organized at present, the critical proponent of consumer welfare might bring two general indictments against the food industries.

In the first place, the manufacturer is primarily unconcerned with the effect of his product on welfare. This may result in nothing more pernicious than the wasteful devotion of a share of our capacity for production to goods which represent no advantage over unelaborated staples, but whenever welfare conflicts with profit-making, the former is generally sacrificed to the extent permitted by our limited protective legislation. As a consequence we have promotion of the unlimited consumption of refined foods like milled cereals and sugar which has caused their consumption to be overstimulated. We have products, such as tomato juice cocktails, which experiments in the writer's laboratory have shown to be unreliable sources of vitamin C, being purchased by the uninformed if not deliberately deceived consumer as worthy rivals of the more certainly antiscorbutic plain tomato juice. We have the patenting of a new bread improver which absorbs 200 per cent. of water and can be used in amounts to produce 15 more loaves of bread per barrel of flour.

On top of numberless such individual perversions of the true function of production, welfare in consumption, consumers are faced with organized pressures against such mild restrictions in their favor as the recently proposed revision of the Federal Food and Drugs Law and the code for canners to require a statement of quality grades on labels. To date such opposition has been effective, probably because we have no strongly developed consumer consciousness in this country.

The second general indictment against the food-manufacturing industries is the charge that they exact excessive remuneration for the services they perform. In the first place, the manufacturer or processor is in a strategic position in regard to price-making. Depending upon the degree of monopoly that he possesses and upon other factors, he more or less decides not only what he will pay the farmer for raw materials but what the consumer shall pay for the product. The depression has enabled him to utilize this power to his great advantage. In spite of efforts of the Agricultural Adjustment Administration to restore what seems to many a more equitable balance between farm prices and prices to consumers, processors and distributors are to-day receiving 62¢ of the consumers' food dollar, as compared with 53¢ in 1929. Pasteurization and distribution make the fluid milk supply an example of an industry so manipulated that since the war ruinously low prices to farmers have been paralleled by relatively slightly changed prices to consumers. In going through the hands of the manufacturer the average food has its money value increased 50 per cent. It is the welfare value of this amount that we are concerned with in this discussion.

In the second place, the food industries have not been free from the inflated salaries and dividends which have characterized large-scale production under our present economic system. The interested reader may turn to the article in the October, 1934, issue of *Fortune* for an account of General Foods which verifies this statement and shows how economies of large-scale machine production and distribution tend to be dissipated before they reach the ultimate consumer.

In addition, the food processor may be accused of levying too heavy a charge upon consumers by supporting costly practices which offer slight or no advantage in consumption. In 1932, a Senate committee found branded goods in packages selling for 60 per cent. more than similar products in bulk. Brands are multiplied until retailer and consumer are bewildered. By a recent estimate we had 10,000 brands of wheat flour, 4,500 of canned corn, 1,000 of canned salmon, etc., and in a single city the housewife must choose from 87 breakfast foods, 46 flours, 93 packaged butters, 101 packaged teas, etc. Not only is it true that in most cases 4 or 5 quality grades are all that are necessary to meet needs, but individual brands have been shown to be of little reliability in identifying uniformity of quality, and consequently do little more than confuse the buyer.

Excessive elaboration is another practice increasing costs to consumers. The modern breakfast food has been aptly described as a pasteboard box of air and advertising wrapped in Cellophane. The consumer may be intrigued by the drama of having his morning cereal "shot from guns," but at present prices this treatment multiplies its cost about 35 times.

Finally, in advertising we have a factor increasing the cost of processed foods out of all proportion to benefits received by the consumer. General Foods, a corporation distributing a group of well-known processsed foods, is said to expend 10 per cent. of its gross sales in advertising. In 1933, this one corporation paid over a million dollars to the publishers of three popular magazines. The trade name of Jell-o was deemed worth $35,000,000 by them in 1933, and their judgment seems to be justified by the fact that this product maintains a position on the shelves of chain stores adjacent to their unadvertised similar product, though the former is held at a 50 per cent. higher price.

In fact, in advertising it has been said that we have a union of the irresponsible industrialists' grasp for profits with a force that not only levies an exorbitant charge upon the consumer, but, as Rorty points out, perverts the integrity of the editor-reader relationship, so essential to a democracy, in all our popular periodicals. Mass advertising makes possible the 5-cent national weeklies and the 10- to 35-cent national monthlies with large circulations and editorial policies dictated by the advertisers. The writer knows of not one that defended the lately proposed food and drugs legislation which asked for simple truth in advertising.

Whether or not the natural scientist denies responsibility for the use made of his discoveries, as a member of society he can not escape the consequences. Controlled reformation of our economic order to insure the more complete utilization of the results of science to improve the welfare of all is admittedly a very complex problem. Perhaps he is unequipped to make important contributions to its solution. However, both as a member of a vocational group claiming the socially responsible rank of a profession and as a citizen possessed of a minimum degree of civic consciousness, he must be critically interested in suggestions for such adjustments. Thus we proceed to proposed methods for improving the consumers' position in relation to the processing of food.

Three lines of action have their proponents. A first is the continuation and extension of the present method of enacting legislative regulation of industrial practices to protect the consumer. The principal weakness of this policy is the lag between the development of the need for restriction and the development of sufficient consumer consciousness and organization to effect the pressure required to outweigh the efficiently organized opposition. The struggle for consumer purchasing power, whatever the

cost to consumer welfare, is likely to be more aggressively pursued than any campaign for his protection. Years of agitation during which unremediable damage to health may result are often required, as the great need and struggle for the food and drugs legislation of 1906 as well as for its revision in 1934 bear witness.

A contemporary trend in food processing which may have peculiarly pernicious results because of the indirection of its effects and the lag in their recognition and control is that of improving the palatability of processed foods. It is highly significant for the consumer that one industrial chemical company announces a new house organ on taste and odor control. The editor of the trade journal, *Food Industries,* writes: "One of the next constructive steps in the production of manufactured foods should be that of conferring upon factory-prepared foods an elusive something that can not be attained in the home. . . . No surer way exists for a manufacturer to maintain his prestige with the housewife than to produce better tasting foods than can be prepared in the kitchen at home." This may seem a laudable exhortation to the reader, but the nutritionist is reminded of the inadequacy of palatability as a guide to food choices and of the propensity of the human race to follow it. In the past the failure of many commercial products to compete with those prepared in the household in flavor has been some measure of protection for the consumer, retarding the adoption of foods which have had their nutritional imbalance increased during processing. When the chemist is employed to create appetite appeal, most of us will be led where he wishes, regardless of truths about composition on labels or in advertising. Possibilities of such attempts are indicated by the reported discovery of a compound which imparts a full butter flavor to a butterless substance, though present only as one part in 50 millions and another which gives a meat flavor when present in minute quantities.

A second method suggested to protect the consumer from practices of the food industries which are unwholesome or uneconomic is the boycott. This may be carried merely to the extent of buying only staple, relatively unprocessed materials in so far as possible and preparing them in the household, as advocated by Consumers' Research, or to the extent of establishing almost complete independence of the food industries by retreat to the haven of a subsistence farm, as urged by the Borsodis. One of the latter, in two books entitled "This Ugly Civilization" and "Flight from the City," describes their experiences as city intellectuals transplanting themselves to a few rural acres where they produce and process most of their family food supply. They maintain that the average woman can still earn more in her own kitchen than in factory, store or office. A certain nostalgia for the simple life that this is seen to represent awakens a sympathetic if not a sentimental response in many of us. But a return to this way of living, doubtfully idyllic even when accompanied by cheaper power and modern labor-saving gadgets, will probably be only an emergency solution for a comparative few. It is unlikely that the skills and hours of household labor required for such an existence would remain either interesting or endurable to those who have lived in emancipation from them or to those whose social and creative aspirations are not satisfied by such a revival of an agricultural economy.

A third response to the problems which science and technology have brought upon man as consumer is based upon a belief that these agents for creating the leisure essential for the good life may be controlled in the interests of all. As Mumford points out in a magnificent analysis of "Technics and Civilization" . . . "while technics undoubtedly owes

an honest debt to capitalism . . . it was nevertheless unfortunate that the machine was conditioned, at the outset, by the foreign institutions and took on characteristics that have nothing essentially to do with the technical processes or forms of work. Capitalism utilized the machine not to further social welfare, but to increase private profit." He proceeds to reason that the full benefits of the machine can come only with a basic reorganization of our economic system, a rationalization of production directing it toward consumer needs rather than producer profits. Then the economies of large-scale machine production, the quality that can be secured under controlled conditions by expert technicians, and the increased leisure may be more fairly shared by all.

The execution of such a reorientation of production will be no simple or easy task. The relative merits of democratic consumer cooperation, socialistic government ownership, fascistic and proletarian dictatorship are widely debated in all the contemporary world. In the secure fastness of his laboratory the natural scientist would perhaps seek peaceful refuge from the conflict without but complete immunity from the pains of our society's adolescence or senility, whichever one deems them, is not likely to be granted.

MAKING MALARIA WORK FOR THE DOCTOR

By Dr. NORMAN TOBIAS
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We have often heard of such trite expressions as "returning good for evil" and it takes "poison to kill poison." Such loose ideas may truly be applied to a disease that is feared throughout the world and numbers hundreds of thousands of victims yearly, namely, malaria. And yet through an accidental discovery this disease has been found to be of inestimable value, as an instrument of good, as a medicinal measure in curing another condition that has caused much more suffering and harm, that human scourge, syphilis, of which there are more than 6,000,000 cases in men, women and children in the United States to-day. Now syphilis is a many-faced disease with symptoms so mild in the beginning that many victims fail to notice them. In an unfortunate 10 per cent., the nervous system often becomes involved, causing mental disturbances or paresis if the brain is affected, locomotor ataxia, if the spinal cord is attacked, or partial and complete blindness if the optic nerves are implicated.

The use of fever or, to be more explicit, inoculating one febrile disease to cure another is not a new discovery. Garrison in his "History of Medicine" points out that the beneficial effects of malarial infection in epilepsy were known to Hippocrates. The ancient Greeks and Romans applied the principle of heat treatment in certain disorders by advocating the use of hot baths and mineral springs for many diseases, a measure which persists to this day. Physicians often note an improvement in many chronic disorders complicated by such febrile diseases as erysipelas. Down through the ages medical men have observed the improvement in chronic skin diseases following in the wake of superimposed attacks of scarlet fever or other contagious diseases.

These older methods of inoculating one disease to cure another are now being used again throughout the world. The germ of erysipelas is sometimes used to combat a form of cancer called sarcoma. Dead typhoid organisms are often in-

jected into the blood to relieve arthritis or other chronic diseases. Inoculating a syphilitic with the germs of relapsing or rat-bite fever as a means of provoking fever in overcoming serious complications in the nervous system has been used in certain countries. All of which brings up the question: why graft one disease upon another serious disease and expect good to come of it? It is all a matter of recognizing fever or internal heat as a factor of good, as a curative agent.

Most folks regard fever with alarm and take active measures to reduce or "break it" as soon as possible. In most cases this is perfectly proper, because fever is uncomfortable and often associated with other symptoms. But still the fact remains that fever is a defensive mechanism on the part of the body to overcome destructive and foreign invaders and signifies that a battle royal is on to determine who shall win, the patient or the disease. The process of fever production sets up certain blood and tissue reactions which usually destroy the harmful infection. Serious infections with little or no fever are usually fatal, and medical men have come to realize that fever in itself is a good prognostic sign. These facts were recognized as far back as 1870, when Weigert proposed his law stating that "local injury or necrosis usually sets up a reparatory process in excess of requirements." Or in other words, as Pflüger stated in 1877, "injury is the incentive to the removal of injury."

Unfortunately, when Paul Ehrlich discovered salvarsan in 1910 he believed that he had at last found a sure cure for syphilis, but subsequent observation has brought out the fact that where the disease has been present for a long time and has invaded such delicate tissues as the liver, heart and brain very little hope of cure can be expected from drugs alone. Chemical treatment can improve the disease to a certain level, but beyond that the response is slight. So fever treatment has come into the field of therapeutics as a remarkable aid in chronic resistant syphilis, whether acquired or congenital, and more specially and successfully in paresis.

It remained for a kindly, humane, eccentric professor in Vienna to assemble and correlate his observations on the effect of fever in mental diseases and to apply it in his daily work. That man was Julius Wagner-Jauregg. This great observer, who recently celebrated his 76th birthday, has been a professor at the University of Vienna for 44 years. He began his studies as a student in that same university under the great internist, Bamberger, the well-known pathologist, Stricker, and the neurologist, Leidesdorf. The latter interested him in mental diseases early in his studies and developed in him a sympathy and practical interest for the unfortunate insane. At the time that Wagner-Jauregg made his observations on the effects of fever treatment in mental diseases, psychiatric treatment was highly theoretical and most of his colleagues were therapeutic nihilists or treatment scoffers. As this kindly professor with bushy eyebrows and large mustache made his daily rounds in the hospital, he took careful notice of each and every one of his mental patients. He was especially astounded at the remarkable amount of improvement in one of his paretic patients who developed erysipelas. This gave him great food for thought, and after assembling data acquired through reading the literature, and observations of many doctors before his time, he first published his theory of fever treatment in 1887. However, his older colleagues jeered at him and criticized his work severely. In 1891 when he began to use tuberculin as a means of producing fever, not only did the faculty rise up in arms against him, but the entire Viennese press printed editorials caustically

criticizing his work and holding him to be a potential murderer. However, Wagner-Jauregg was tolerant of his critics and quietly continued to study the problem. In his study of endemic cretinism in Styria he developed powers of organization with mass treatment which later fitted him to inoculate hundreds of patients with malaria and tabulate the results.

With the onset of the great war his work was more or less forgotten until 1917 when he resumed his experiments. At this time the faculty consisted of many new, young and open-minded members who quickly took recognition of his work. He began by treating paretic soldiers with malarial inoculations which he found to produce the best results. His work in this field has been so successful that it is now being used throughout the world. His recognition was climaxed with the bestowal of the Nobel Prize in 1927.

When we speak of malaria we mean a particular type called benign tertian caused by the plasmodium vivax parasite. This type of malaria is practically never fatal and can be readily cured by administering quinine. The Middle West and Southern states are practically never free of it and sporadic cases occur in every state of the Union. It is naturally transmitted by the bite of the infected Anopheles mosquito. In contrast to this mild form of malaria we must recognize the more serious or malignant form which is never used in the treatment of disease, namely, aestivo-autumnal malaria.

Since infected mosquitoes are not always available and for practical purposes are not ideal nor safe sources of malaria, physicians utilize the blood of patients already infected with the disease. The syphilitic recipient is injected under the skin with blood from the malarial donor and the physician waits for the "take" to occur. This usually requires about 10 days, after which the paroxysms of fever and chills followed by sweating occur with more or less regularity. In the 24 to 48 hour free intervals the patient is usually comfortable, but during the attacks of fever he appears quite ill and has a temperature of 104° or higher. The patient is permitted to have 8 or more paroxysms and then the malaria infection is overcome rapidly by administering quinine. The peak of success from this type of treatment occurs in about 12 months with gain in weight and marked freedom from mental and physical ailments.

Post-mortem studies have shown how malaria acts on the nervous system. It sets up a powerful stimulation in an extensive group of protective tissues called the reticulo-endothelial system which is found in the spleen, bone-marrow, liver, brain and lining of the smaller blood vessels. This stimulation produced by the malarial germs causes an exodus of cannibalistic cells called histiocytes or wandering cells, which rush into the capillaries of the brain and other organs and devour the hidden, harmful nests and deposits of the syphilitic germ which have interfered with the normal blood supply and breathing of the brain and nerve cells. All this through the medium of the fever which sets the wheels in motion for the malarial organisms to do the work. And so we can be thankful to Professor Wagner-Jauregg for giving us malarial therapy in treating diseases which long have been regarded as hopeless and incurable.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE MINOR PLANETS: STRAY SHEEP OF THE SOLAR SYSTEM

By Dr. A. O. LEUSCHNER

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THE solar system, of which the earth on which we live is a part, consists of a host of celestial bodies whose motion is controlled primarily by the gravitational attraction of the sun. This attraction causes them to move around the sun in more or less elongated ellipses, known as orbits, with various periods of revolution, ranging from 88 days for the planet Mercury, nearest to the sun to thousands of years for some comets.

Best known among the members of the solar system are the major planets Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune, in the order of their distances from the sun. They have relatively large mass, or weight, and size. The heaviest of them, Jupiter, has a weight approximately one one thousandth that of the sun. There is also Pluto, discovered in 1930, far beyond the orbit of Neptune. Pluto is still classed as a major planet, because of the expectation of astronomers that another such planet existed beyond Neptune, but its weight and size have been disappointing, being probably less than those of the moon. The moon's weight is about one eightieth that of the earth. The earth's weight in turn is about one three hundred thousandth part of that of the sun. Other major planets besides the earth have moons revolving about them, but we are not concerned with them to-day.

The distances of the major planets from the sun range themselves in a certain sequence, known as Bode's law. This law is entirely empirical, but it led astronomers to suspect the existence of another major planet between Mars and Jupiter, at a distance from the sun of approximately 2.8 astronomical units, the astronomical unit being the distance of the earth from the sun. Organized search by astronomers failed to reveal such a body, but on January 1, 1801, the Sicilian astronomer Piazzi accidentally noticed a strange moving body while looking for a certain star. He named it Ceres, and it was hailed as the missing planet predicted by Bode. Its distance fits Bode's law, but its size and weight, like those of the recently discovered Pluto, were a source of great disappointment. The diameter is only about 500 miles, less than one seventh the diameter of Mercury, the smallest known major planet. Still more puzzling was the discovery of three more such objects by 1807. In distinction to the major planets, these small bodies became known as minor planets. Ceres, the first discovered, went astray, and soon was lost from sight. Fortunately, months later it was located again among the stars, as a result of calculations under the Newtonian law of gravitation.

This straying from their paths of the minor planets presents perplexing problems to the astronomer. Straying sheep are rounded up by the shepherd's watchful dogs, and are brought back to the path which the flock is to follow. Minor planets, however, have to be followed individually by arduous computations if they are to be sighted again. Their breaking away from the elliptical orbit,

however, is not capricious, as in the case of sheep, but is due to the universality of Newton's law of gravitation, which subjects the minor planets not only to the attraction of the sun, but also to that of the major planets of the solar system. The fact that we know why the minor planets stray from the paths prescribed for them by the sun offers little comfort to the astronomer, considering the enormous difficulties involved in calculating the action of the major planets, known as perturbations.

The discovery, up to 1807, of four minor planets between Mars and Jupiter stimulated search for others. By 1890 more than 300 of them were known. Up to that time the discovery of minor planets was an arduous task. In the telescope a minor planet looks like a faint star. To identify it as a planet it is necessary to observe that it moves relatively to neighboring stars. That means watching the stars visible in the telescope, at least for several nights in succession. This can only be done with the aid of accurate maps of the fainter stars. Such maps, therefore, had to be made with great labor.

The planet's orbit around the sun generally can be approximately calculated if its position has been measured accurately at three different times. The accurate positions are secured by measuring parallel and perpendicular to the equator the planet's angular distances from the position of a star. The accuracy of the planet's measured position thus depends on the accuracy of the star's position.

Beginning with the year 1890 the flock of minor planets began to multiply enormously with the use of photography in searching for them. A plate exposed in the focus of a photographic telescope which follows the daily motion of the stars by clockwork and other guidance, reveals the stars as points on the plates, while the moving minor planets produce small trails. The position of the minor planet relative to the stars may be accurately measured. Further exposures are made in the days and months that follow to secure the positions necessary for the calculation of an orbit.

Originally astronomers followed and accurately measured every new minor planet. This requires the calculation of its approximate elliptic path. Otherwise it will go astray and that is what is happening now with the vast majority of new minor planets. At the time of discovery they are near the earth, with the sun in the opposite direction. As a planet moves away from this favorable position it becomes invisible. After at least a year or more, it again revolves into the favorable position of opposition. To find it then, the perturbations of the major planets must be taken into account by complicated mathematical methods. It is not a question of keeping minor planets rounded up like a flock of sheep, but every planet goes its own way and has to have an individual shepherd who subjects its wanderings to calculations.

The largest number of minor planets discovered in any year was in 1931 when 391 were found. Since 1910 over 3,000 have been discovered. Of this large number only one in five has an orbit computed with adequate accuracy to warrant a prediction of future motion with confidence. Such planets receive a current number. So far, 1,301 planets have received numbers out of more than 5,000 discovered since the beginning of the last century. For some 40 of these, the predictions at best must be uncertain. For an additional 85 search so far has been of no avail or if found, they had strayed far from the predicted path. Another 306 of the 1,301 have either not been seen since 1930 or they have not been observed on sufficient returns for reliable predictions. Not all minor planets which show as trails on plates are listed, but sample counts of selected regions have been made from available plates which reveal that there are about 50,000 minor planets within reach of the largest telescopes.

The early observations may be represented by quite a range of preliminary orbits, and only later observations can reveal how close the adopted preliminary orbit is to the real one. When a preliminary orbit is known, so-called special perturbations due to major planets may be calculated step for step with their known weights or masses. This is repeated until an orbit results which with these special perturbations enables the astronomer to predict the position of the minor planet. But it has not been possible to keep track in this manner of all the numbered minor planets. There is another method known as general perturbations which gives the total effect of the action of the major planets at any future date. This method is used increasingly and has so far been applied to 223 planets. It is particularly effective if planets of similar orbits are taken in groups, as, for example, all the planets which move around the sun twice as fast as Jupiter, more or less. No planet moving less than 700 seconds a day can be followed without consideration of the perturbations. If its motion is between 700 and 850 seconds and the ellipse is only moderately elongated, or if the motion is more than 850 seconds and the ellipse is highly elongated, there is also no possibility of adequate prediction without consideration of the perturbations. The process of general perturbations enables the discoverer to pick up a minor planet after decades without the intervening observations or calculations necessary with special perturbations.

Gradually the great significance of the study of the motions of the minor planets is becoming more and more apparent. May I touch merely on a few of the problems, in which they are being recognized as having an important part. Precise star positions and maps are required for some of the most important studies now under way, such as the structure of the universe. While precise star positions originally served for the accurate determination of planet positions, it is now recognized that when the motion of the planet is precisely known, the positions of the stars which it passes in its course can be improved by reference to its orbit.

Motion involves intervals of time. Our daily time is measured by the rotation of the earth. Irregularities of the rotation of the earth would cause apparent straying of a minor planet. In turn, any existing irregularity in the rotation of the earth may come out of the study of planetary straying.

Many problems depend upon an accurate knowledge of the distance of the earth from the sun, our astronomical unit. Orbits in the solar system are calculated with this unit as a scale. If the minor planet in its elongated orbit should come sufficiently close to the earth so that its distance can be measured in miles by triangulation, the exact length of the astronomical unit may be determined. There are several such planets, one of which cuts into the orbit of Venus and under the most favorable circumstances can come as close as six and a half million miles to the earth, as compared to the sun's distance of ninety-two and a half million miles. Unfortunately, the few highly important minor planets of this kind, except one, have gone astray. The exception, known as "Eros," has been used in two international astronomical campaigns for the determination of the sun's distance.

Straying of minor planets, as has been noted, is caused by the major planets. *Vice versa,* a close approach of a minor planet to a major planet enables us to determine the latter's mass or weight. Minor planets have many points of resemblance to comets, another group of bodies of the solar system. Some of these travel in highly elongated orbits with periods running into thousands of years. Comets and minor planets have sprung either one from the other or from a common source, yet to be ascertained.

Minor planets are observed from a

moving earth, and the calculation of their orbits requires an accurate knowledge of the earth's orbit around the sun. With all other causes of straying eliminated, the motion of the minor planets gives opportunity of perfecting our knowledge of the orbit of the earth.

These are but a few illustrations of the parts minor planets play in the scheme of astronomical science, but how can we account for their existence and the variety of orbits in which they move? Evidently much light might be thrown on this question if by perturbations traced backwards into the distant past we could lead them back to where they came from. Such investigations have been made and it has been found that at certain epochs in the past families of planets started from the same point with reference to the sun. Each family may thus be the remnants of a disintegrated larger body. Whether the parent bodies, if traced still further back, again be found to be parts of a still larger original body is at present a matter of speculation. Such parent bodies may have given rise simultaneously to comets and minor planets.

Thus minor planets and comets must be accounted for in any theory of evolution of the solar system. They form as important a part in this problem as the study of the distances and motions of the nebulae in the problem of the nature of the universe.

THE MOSAIC OF NATURE

By Dr. GEORGE J. PEIRCE

EMERITUS PROFESSOR OF BOTANY, STANFORD UNIVERSITY

If a space of air and soil were absolutely cleared of every living thing, by war or fire or volcanic eruption, what would follow? What has followed? By degrees, and by invasion or immigration or spreading from the surrounding air and soil, the space has become occupied and fully occupied, as before. There has been reestablished that balance, that mosaic, of nature which exists in every new country and in every old country sufficiently old and undisturbed. In every country less new, and in every area only recently devastated, the mosaic is still in the making. Not only is the mosaic still in the making, but there is such a shuffling among the possible components that some of the pieces may be broken and the pattern may be greatly changed.

This reconstruction is not like that which follows an evening's work upon a picture puzzle, the restoration of pieces of various shapes to the spots from which they were sawed and taken. Nor does it follow a design preconceived in the mind of the artist and prefigured to the eyes of the artisan. Instead, the reconstruction results from repeated rearrangements among themselves of the moving, living, struggling pieces of the picture.

We may call some of the pieces plants, others animals; but in doing so we must include ourselves also, for man is a part of nature. To be sure, it is quite contrary to man's absurd estimate of himself to think of him otherwise than as "the lord of creation"; but while man sometimes thinks of himself as "controlling the forces of nature," it requires only a moderate earthquake or even the procession of the seasons to show him that he is powerless even to delay the movements of the earth, either the wrinkling of its crust or its turning upon its axis.

He has adjusted gravity to his own benefit, and makes it support his skyscrapers and furnish him with hydroelectric power; but the birds do better,

and even the trees—furnished with running water throughout!—anticipated his high buildings. He has built houses for protection and defense; but fur and claws accomplish both. He has devised societies; but no more perfect or monotonous democracy than the forest, no more complete subjection of labor to capital than his own dependence upon water and the products of the soil. He must struggle for space and for subsistence with the other living—and with the lifeless—components of the mosaic of nature. And ultimately he succumbs to a staphylococcus or a deficient vitamin or an unbalanced hormone, and so keeps his place in that continuing procession of living beings stretching from the beginning of time until its end.

We must recognize, too, that while all these living pieces of the mosaic perform constructive rôles in the making of the picture, some are constructive in the sense of manufacturing and building, while many others are destructive, living upon and destroying the products of the first. The sheep is dependent upon the grass which makes sugar, but man depends upon the sheep for food and warmth. Both man and sheep return to the air and soil the carbon dioxide gas, the mineral matters and the water of which their bodies were built.

An impressive part of the mosaic of nature is this maintenance of soil and air fertility for generation after generation. As long as there is no decline in the supply of energy from the sun for doing the work of the world the useful composition of air and soil will be maintained. For in the hours of daylight, while carbon dioxide gas is being absorbed, abstracted from the air by green leaves and combined with water to make food in the form of sugar, the oxygen content of the air is maintained by the oxygen liberated in food manufacture. As constantly, each living thing, by its respiration, is returning carbon dioxide and water to air and soil. By these two processes the mosaic of nature is kept intact. The pressure and the composition of the air remain the same in any given area for century after century.

In the mosaic of nature there is generally food enough for all. There may be starvation, death, locally, as the result of war or other destructive calamity; but in the scheme of nature production and consumption are equal. There is no accumulation, nor is there any deficit. Those plants and animals which are short-lived make and store enough food to satisfy their own requirements, to enable them to reproduce, and to provide their offspring in seed and egg with sufficient food to carry them through that period in which they are too small or too weak to shift for themselves. Longer-lived plants and animals accumulate in their own bodies such stores of food as will carry them over the periods of non-production, over the winter, through the dry season; and some of the cleverer animals have acquired the arts of harvesting and storing so that, although they grow thin, they do not necessarily die.

It is true that this general balance of production and consumption, of supply and demand, while wonderfully perfect throughout nature as a whole, is not always and everywhere attained. Individuals, communities or larger groups of organisms may suffer or even perish. Nevertheless, the oceans maintain their populations of fishes, seaweeds and plankton unchanged year after year, unless disturbed by some intrusion of creature or of force. The land each season produces its blanket of grass and herbs or adds height to its forest cover and so maintains its animal population year after year. Here and there invasion, which may exhibit itself as war or as epidemic, according to the size of the invader, may destroy a part or the whole of the living population. Man may fell or fire the forest, mosquitoes may distribute malaria, floods may devastate, drought and wind may even remove the soil. Yet all these departures from the

general scheme reveal themselves because they are exceptions. Generally there is food enough in nature for all.

Man possesses qualities which distinguish, sometimes mislead and often threaten to destroy him. He has more inventive power than any other living thing. Some of his inventions come dangerously near being fatal to him. He is called a social animal. His invention of the city illustrates both. For a city is of all things the least able to support itself. If it grows too fast or too large it will outrun the means of subsistence and die of hunger in cold and filth. Man's immodest effort to depart from the pattern of nature has resulted in certain immense advantages to himself individually; but it has exposed him at the same time to grave personal dangers, and more than once it has involved threatened if not actual racial destruction.

Not only by interfering with the mosaic of nature through concentration of individuals into limited areas, but in numberless other ways also man has distinguished himself as both ignorant and bold. Without study and knowledge of the world he lives in he determines to do what desire dictates. He fells the forests, clears the land, sows an imported grain, combats all previous occupants of the area, regardless of the doctrine of prior rights, endures the caprices of the weather, harvests the survivors of the struggle for existence between the old families and the newcomers, eats and sows these survivors and conceives himself to be prosperous if he has a salable surplus.

But if his breaking the native sod, clearing the land and sowing to grain be followed by prolonged and intense drought, the crops will fail, there will be no cover and no binder to the soil, the wind will pick it up, carry it away and finally deposit it in those places where it is least desired. On the marginal lands of the Dakotas and of the western dry belt the would-be farmer smashed the mosaic of nature. He has suffered variously for years, producing crops of political, social and economic ideas repugnant to those less bold or less original persons who remained where water, soil and climate are less threatening. Finally, the continued threat has been carried out, good soil has been lifted and whirled away, the former owner impoverished, the recipient embarrassed. A return of the soil to nature is impossible. The mosaic is not only broken, it is dissipated.

Similar danger threatens man's use of sand dune areas. If he increase whatever holds the sand together, be it plant cover, suitable buildings or binding oil or asphalt, then is his procedure safe; but let him cut the natural coat, sever the natural binders, and the sand will begin to move, irresistibly, in the direction of the prevailing wind, burying farms and settlements or shifting channels, but in the end establishing a new and not always welcome pattern of the mosaic.

Erosion control is more than a charitable impulse, a vote-getting device or a euphemism for a dole. It is a conscious, intelligent effort to repair, as rapidly as possible, what has been damaged by road cutting, by down-hill instead of horizontal plowing, by the destruction of the forest cover by fumes and by other interferences with the established pattern of nature. It checks the run-off after rain and melting snow; it prevents the scouring and scoring of hillsides; it reduces the risk of freshets; it lightens the load of silt carried by the streams. It is one of the finest examples of man's undoing by cooperation the harm which he has done individually in unintelligent self-interest. It is a partial fulfilment of the promise which the biologist sees of increased comfort, improved health and greater happiness for all in such study and understanding as will lead man to be a harmonious and not a rebellious part of the mosaic of nature.

THE ROMANCE OF MODERN EXPLORATION

By ANSEL FRANKLIN HALL

CHIEF, FIELD DIVISION OF EDUCATION, NATIONAL PARK SERVICE

The story of exploration in the desert Southwest offers opportunity for introducing a bit of the thrill that goes to men who are privileged to push into new country. It may surprise you to know that this land of ours still offers opportunities for real exploration. There are still vast areas that are as yet practically unknown to white men—areas that challenge the interest of the scientist and the man who would seek the last frontier of the old West. Off in the dim blue distance far to the northeast of the Grand Canyon of the Colorado lies a vast, colorful, picturesque country—the home of the Navajos and of prehistoric tribes that developed a civilization that disappeared from the face of the earth long before the new world was discovered by the white man.

But this country is not all desert. The sacred mountain of the Navajos lifts its huge bulk so far into the blue that its 10,000-foot summit is clothed with a dense forest of pine, spruce and fir such as one would expect to find 2,000 miles farther north—but certainly not in the desert Southwest. Surrounding its flanks is the great Rainbow Plateau, which is cut by deep canyons in which prehistoric cliff dwellings nestle beneath the overhanging ledges. Farther toward the east, high straight-sided mesas are a common feature of the landscape, and desert erosion has caused the weird and unique features of the Monument Valley. Here are to be found natural bridges in various stages of evolution, the most perfect of all resembling a huge rainbow which lifts its arch higher than the dome of the national capital building in Washington.

Into this weird country went a band of explorers in the summer of 1933 and again in 1934—engineers, geologists, biologists and other scientists whose duty it would be to map the area and to penetrate as far as possible into the interior in a preliminary reconnaissance that would determine the plans for future field seasons of more intensive exploration and scientific investigations. These men were all volunteers—men who during the remainder of the year were students and instructors in the universities and colleges of California and the East.

When the auto caravans left California and New York City early in June on the trek to the Southwest, the spirit of adventure ran high. The first several hundred miles of the journey were clear sailing along wonderful highways, but at Flagstaff, Arizona, the party turned north into the desert. Roads became worse and worse. Deep sand and chuck holes resulted in two broken axles. The last hundred miles were scarcely more than a track across the desert. Finally the supply base was reached—the little outpost called Kayenta at the northern end of the Navajo Indian Reservation. From here on the party must make its own roads and trails. Here the expedition was divided into smaller field parties, each of which would push into the unknown afoot and with pack train or would endeavor to find a way across the desert in their sturdy station wagons. Before the field parties set out, however, all members of the expedition helped to construct a landing field, for the expedition's reconnaissance plane was due to arrive in two or three days; the nearest airport was 175 miles away toward the south. Meanwhile the pack train was organized and the archeologists and biologists started northward into the canyons of the Tsegi in an attempt to cross Skeleton Mesa to meet at an ap-

pointed rendezvous on the flanks of Navajo Mountain a month later.

The following days were filled with real adventure for the archeologists. Frequently large prehistoric ruins were to be found nestled in recesses under the overhanging cliffs. Some of these ruins were accurately dated by means of borings taken from the timbers which had been used in their construction. In other places the only indications of primitive inhabitants were the fragments of broken pottery left here almost one thousand years ago. The birds, mammals, reptiles and plants of the region, as they exist to-day, in themselves present an interesting study—but all have a bearing upon the life of the ancient people. The biologists made a definite effort to correlate these field studies with the archeological discoveries.

Meanwhile the engineers were at work with plane tables and transits running stadia traverse and triangulation which would enable them to produce a base map of the area. We had expected when we entered the country that there would be some 700 square miles to study, but the region proved much bigger than we had anticipated, and we soon discovered that we had on our hands the problem of exploring and mapping some 3,000 square miles. A preliminary map was made, and this year we expect to return to concentrate upon the making of an accurate contour map of the areas where intensive field work will be in progress.

Bounding this region at the north are the deep canyons of the San Juan and Colorado Rivers. Entirely inaccessible by trail—the only means of penetrating these chasms seemed to be by boat. It would be a hazardous venture, attempting to make the passage through these 200 miles of canyons—but there was no lack of volunteers to man the seven small boats which were specially constructed for the purpose. There was anxiety in camp on the day that the small fleet was launched on the muddy waters of the San Juan. Would they successfully run the rapids and come through unscathed? After three weeks—weeks of anxiety for other members of the party—a truck was sent to Lee's Ferry at the lower end of Glen Canyon to bring back the pioneers and whatever boats might have survived the ordeal. But the fleet arrived without mishap. The members of the party told exciting stories of cliff ruins and Indian pictographs, and of the unique fauna and flora that must certainly be studied during future field seasons. The passage through the canyons had been demonstrated to be practicable, and we expect this year to send another group of explorers and scientists into the canyons to make detailed studies.

Our geologists found many intriguing problems in this almost unknown region. Several of them engaged in the fascinating game of hunting fossil dinosaur footprints. Many were discovered, some of them large enough to have been made by the giants of the ancient world, others as small as the footprints of *modern* lizards. Plaster casts were made of more than 200 impressions so that actual facsimiles can be made for the purpose of further study.

But with the exception of the Chinle, the formations of the Navajo country are almost barren of actual fossils. Keen-eyed geologists had been looking for fossils in the Navajo Sandstone for half a century and never a vestige had they found of anything that might tell of life on the earth when these thousands of square miles of red sand had been laid down. Would *our* geologists be fortunate enough to find such a treasure? Surely in all those thousands of square miles there might be—but no, week after week went by, and boots, clothing and patience were worn and tattered from scrambling over sandstone and climbing down into seemingly inaccessible canyons. No, the search was a failure. But hope dies hard. On the last day of the

season, when the members of the main party were assembling their belongings in the base camp for the morrow's start on the thousand-mile trek back to the Pacific Coast, four geologists said, "Let's make just one more final search in the rocks up in the Tsegi Canyon." They did. Disappointment again. Knocking off work at sundown they started the long wearisome 10-mile hike back to camp. The red sky turned to purple. It was getting hard to see. Suddenly one of the men said, "What's this?" Just a light spot on a red rock that almost any one, even a geologist, would have passed by. But it looked odd. A tap of a geological hammer and there, sure enough, lay a white bone embedded in the rock. A fossil *at last* in the Navajo Sandstone! A discovery of such importance would normally have been left in place, but this was disintegrating surface rock, so there was nothing to do but carefully gather the fragments.

Late that night the party, jaded but triumphant, burst into the campfire circle with the startling news. And it proved to be even more startling than they suspected, for when these precious fossils were sent to the University of California for identification and study they proved to be the remains of an entirely new type of small bird-like dinosaur. And most important of all, this find represented the very first fossil of any kind ever found in the Mesozoic rocks of the Southwest.

1934—second assault upon the northern Navajo country—discovery of a very ancient Basket Maker burial cave, which yielded rich finds—and the unsolved mystery of seventeen headless mummies; then there were mammals, birds, reptiles, insects, many of them never before reported from Arizona, and some of them entirely new to science; also an unexpected geological find in a small cave that produced more than 100,000 fragments of Pleistocene bones—an entirely new fauna for this region; time prevents our listing even the major thrilling discoveries which resulted from that season's intensive field work.

But the job of exploring and studying this fascinating area of desert, mesa and canyon is far from completed. Several seasons of field work will be required before the major problems are solved. Some 2,000 square miles still remain beyond our present horizons. And so about the middle of June another party of scientists and explorers left New York, under the leadership of Dr. Charles Del Norte Winning, of New York University, while at the same time the western caravan started from California. What does the season of 1935 hold in store for these adventurers? Nobody knows! That's what makes exploration such a thrilling fame!

INTERNAL FRICTION IN SOLIDS

By H. WALTHER

PHYSICAL RESEARCH DEPARTMENT, BELL TELEPHONE LABORATORIES

WHEN a bar of carefully annealed aluminum is held in the middle and struck at one end, the sound emitted by it may be heard for more than a minute. If the same is done to a bar of lead, the absence of any musical note is usually dismissed with the remark that the bar is "dead." Now, of course, the aluminum bar is just as dead as the lead bar, if both are regarded as inanimate objects; and the lead bar is just as much alive as the aluminum if both bars are considered in terms of their constituent atoms or electric charges.

Then why do we hear the ring of the aluminum bar and not the lead? The answer lies in their difference in behavior toward mechanical vibration. In the aluminum bar the longitudinal vibration produced by the blow is relatively vigorous and is sustained because internal resistance to motion of elongation and contraction is small. The energy imparted to it is gradually radiated into the air, and some of it reaches our ear. In lead, on the other hand, internal resistance to strain motion is enormously large as compared to aluminum. The result is that the vibration is in the first place only great enough to be barely audible, and furthermore dies out so fast that within one tenth of a second the displacement at the ends of the bar is reduced to about one millionth of its original value. In this case practically all the energy is *dissipated* within the bar and goes to raise the temperature of the material. The amount of heat generated, of course, is very small indeed, due to the extremely small amplitudes of motion involved. For instance, in a lead bar ½″ in diameter and 30″ long, a light blow at the end produces an amplitude of motion of about 10^{-7} cm. The corresponding rise in temperature would be roughly 10^{-14} degree centigrade per second, a rate of heating which, if sustained under perfect insulation, would require three million years to raise the temperature of the bar by one degree!

As low as this rate of dissipation of energy in lead seems, it actually is unusually high among solids. To distinguish between various solids in this respect there is used what is known as the *dissipation constant* of the material. This quantity is based on vibrational measurements of a particular sample of the material and is defined as the ratio of mechanical reactance to mechanical resistance of the sample. Mechanical resistance and reactance are terms quite analogous to the more familiarly known corresponding electrical terms. Thus in a bar vibrating longitudinally, the mechanical resistance measured at one end is simply that quantity which when multiplied by the square of the velocity of motion of that end gives the power dissipated in the bar. Just as an electrical system, a mechanical system involves two reactances. One is the mass reactance, which is the product of effective vibrating mass by 2π times the frequency; and the other is the elastic reactance, which is that quantity which when multiplied by 2π times the frequency gives the force per unit displacement. The two reactances are numerically equal when the bar is vibrating at one of its natural frequencies, and so it is immaterial which one is used in the calculation of the above ratio. The elastic reactance, also called stiffness reactance, is the more convenient one to use. In a bar vibrating longitudinally, the elastic reactance is proportional to Young's

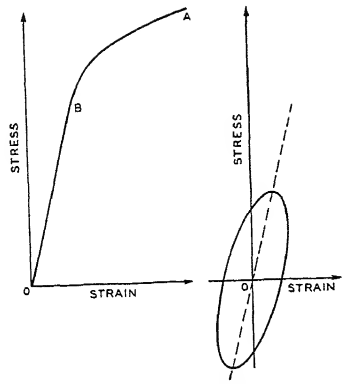


FIG. 1. ALTHOUGH MOST ENGINEERS THINK OF THE STRESS-STRAIN DIAGRAM AS A SINGLE LINE OA CURVING BEYOND THE ELASTIC LIMIT B, MORE REFINED MEASUREMENTS SHOW THAT FOR EVEN THE SMALLEST DEFLECTIONS THE DIAGRAM IS A CLOSED LOOP. THE AREA OF THIS LOOP IS A MEASURE OF THE INTERNAL RESISTANCE, AND THE SLOPE OF ITS SIDES AT ANY POINT IS A MEASURE OF THE ELASTIC REACTANCE.

modulus E, and the resistance is proportional (by the same factor of proportionality) to $\omega\ \mu$, where $\omega = 2\pi f$ and μ is the internal viscosity of the material. So that numerically the dissipation constant of a solid is given by

$$Q = \frac{E}{\omega\ \mu}.$$

The viscosity μ varies approximately inversely as the frequency, and since E is

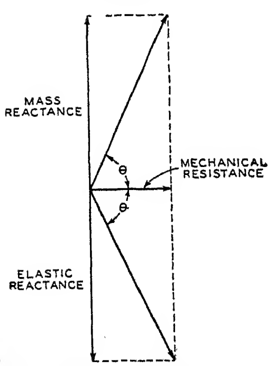


FIG. 2. THE VECTOR DIAGRAM FOR A BAR VIBRATING AT RESONANCE ALWAYS CONTAINS A RESISTANCE VECTOR. THE PHASE ANGLE θ OF EITHER OF THE IMPEDANCE VECTORS WILL THEN BE LESS THAN 90°, AND SINCE $Q = \tan\theta$, THE DISSIPATION CONSTANT WILL ALWAYS BE FINITE.

found to be independent of frequency, the quantity Q is a constant as far as frequency is concerned. From a physical standpoint, the magnitude of Q then is a measure of the relative magnitudes of reactance and resistance present in a given sample of the material. Thus far no material free from mechanical resistance has been found. The determination of Q does not necessitate a direct knowledge of E and μ, however. These two quantities may be calculated from easily made measurements of response at certain frequencies, as shown in Fig. 2. When the amplitude at resonant frequency f, and the frequencies f_1, f_2 at which the amplitude is $1/\sqrt{2}$ times this value are known, we have the relationship

$$Q = \frac{f}{f_2 - f_1}.$$

In the simplest case, then, the dissipation constant can be obtained directly from three measured frequencies.

Considerable work has been done in these laboratories on several phases of the subject. In Fig. 4 is shown H. C. Rorden with the apparatus used for measuring internal dissipation of solids. The slender bar to be measured, shown in the center of the picture, is supported at its middle on a rigid mounting. A magnetic receiver structure is placed near each end. An oscillator connected to one of the receivers is tuned to the resonance frequency of the bar. The resulting longitudinal vibration of the bar induces a voltage in the second receiver, which is amplified, rectified and read on a meter. The tuning of the driving current is controlled by the precision condenser on Mr. Rorden's right, and the response of the bar is read on the meter beside it.

A list of typical solid materials reveals a very large range of values for the dissipation constant. A minimum of 30 for the Q of a hard piece of lead and a maximum of 50,000 for a soft piece of aluminum are not unusual. It is neces-

sary to state whether a given material is hard or soft because when lead with a Q of 30 is softened by annealing, the Q may be increased to a value of 200. Similarly, when a soft piece of aluminum with a Q of 50,000 is severely cold-worked by rolling or bending, the Q may be reduced to 8,000. Again, of two bars of steel identical in size, shape and composition, but one of them hardened by heating and quenching and the other softened by careful annealing, one finds upon tapping their ends that it is the soft one which rings the longest. The dissipation constants of most solids are found between the two extremes of lead and aluminum just mentioned. The table below gives values of Q for most of the solids investigated thus far. The figures indicate orders of magnitude rather than specific values, because, as pointed out above, considerable variation is possible for a given material under various conditions of internal strain.

Quartz (fused)	over 100,000	Copper	3,000
Aluminum	50,000	Nickel	2,000
Brass	40,000	Zinc	1,900
Duralumin	30,000	Glass	1,600
Iron	20,000	Carbon (graphite)	900
Permalloy (80% nickel)	9,000	Tin	800
Silver	6,000	Hard rubber	50
		Lead	30

It is interesting to note that the order in the list bears apparently no relation to other physical properties. Thus we have two of the softest metals occupying positions near opposite extremes of the table. Two solids like zinc and glass, on the other hand, differ greatly in hardness and in electrical resistivity; still their mechanical dissipation constants are nearly the same. Again, carbon and tin are almost alike from the standpoint of mechanical dissipation; yet if we should arrange the list according to melting points, we should find the one at the head and the other at the bottom of the list. But the apparent non-correspondence with the more well-known physical properties and the extremely large range of values of dissipation constants might furnish a means for investigating hitherto unsolved problems involving different kinds of solids and different states of internal strain or structure for a given solid.

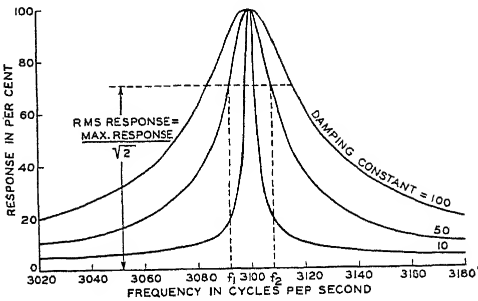


FIG. 3. TYPICAL FREQUENCY-RESPONSE CURVES FOR RESONANT BODIES. THE GENERAL EXPRESSION IS

$$Q = \frac{f}{\left[\frac{r}{\sqrt{1-r^2}}\right](f_2 - f_1)}$$

WHERE f_1 AND f_2 ARE TWO FREQUENCIES AT WHICH THE RESPONSE IS THE SAME FRACTION r OF THE MAXIMUM RESPONSE R. THE EXPRESSION BECOMES UNITY WHEN $r = \frac{R}{\sqrt{2}}$.

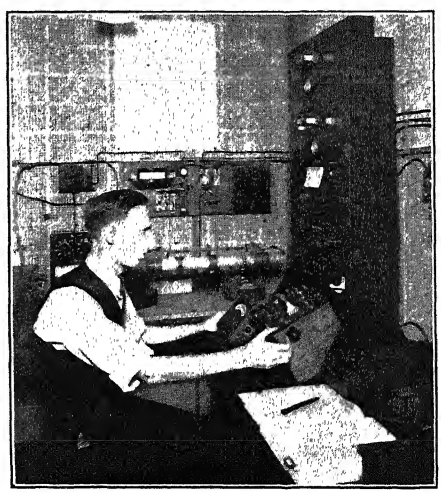


FIG. 4. APPARATUS USED FOR THE MEASUREMENT OF INTERNAL DISSIPATION OF SOLIDS.

VENERABLE BEDE,

BORN IN THE BISHOPRIC OF DURHAM, ENGLAND, IN A.D. 672 OR 673; DIED ON MAY 26, A.D. 735; BURIED IN THE CHURCH OF THE ABBEY OF ST. PAUL, AT JARROW, IN THE PALATINE OF DURHAM.

THE PROGRESS OF SCIENCE

BAEDA VENERABILIS (672–735)

TWELVE centuries have passed since Baeda (Beda, Bede), one of the first of the British scholars of the Middle Ages, completed his work at Jarrow. Four years before his death, which probably occurred in 735, he added a note to his Magnum Opus, the "Historia Ecclesiastica gentis Anglorum," setting forth in brief the major events of a life passed in the monasteries of St. Peter in Wearmouth and St. Paul in Jarrow. The note reads in part: "I was born in the territory of the said monastery, and at the age of seven I was, by the care of my relations, given to the reverend Abbott Benedict—to be educated. From that time I have spent the whole of my life within this monastery devoting all my pains to the study of the scriptures; and amid the observance of monastic discipline, and the daily charge of singing in the church, it has ever been my delight to learn or to teach or to write"—*semper aut discere aut docere aut scribere dulce habui.* What more noble epitaph for a scholar!

Since the current year marks the twelve-hundredth anniversary of the death of Baeda, it is fitting to recall in a scientific journal his contributions to science, even though they were of minor importance when compared with the "Ecclesiastical History," which he completed in 731. In this field he wrote upon physical sciences ("De Natura Rerum,") his material being chiefly gathered from such writers as Isidore of Seville who, in turn, had depended largely upon various earlier Latin writers. This is seen in his treatment of such subjects as the rainbow, volcanoes, thunder and the salt in the seas. He also ventured upon the vexed question of the church calendar ("De Temporum Ratione"), chronology, finger reckoning ("Tractatus de computo, vel loquela per gestum digitorum"), fractions ("De ratione unciarum") and the difficult subject of computation in the age of Roman numerals and of calculation by counters.

It was he who introduced into England the measuring of time from the birth of Christ, attributing it to Dionysius, who had announced his system in Rome beginning with March 25, 527, although it appeared in papal documents somewhat earlier.

The representing of numbers by means of fingers has a long history, as indeed has the computation by similar devices. Even at the present time in certain parts of the world people multiply 8 by 6 by leaving three fingers up on the left hand to represent $5+3$, the rest (2) being closed; they also leave 1 finger upon the right hand, the rest (4) being closed. Then they add the upright fingers $(3+1=4)$ and multiply those which are closed $(2\times4=8)$, thus obtaining 48. The process requires the learning of multiplication facts only to 4's.

The contribution made by Baeda was to the representing by the fingers of larger numbers than were commonly used in the period in which he lived. A manuscript copy of his works, with illustrations of the finger arrangements, is now in the Biblioteca National at Madrid, dated about 1140. Another description of these symbols is in the "Codex Alcobatiensis" in the same library. Of the several early printed illustrations of finger numerals the one in Pacioli's "Sūma de Arithmetica Geometria Proportioni & Proportionalita" (Venice, 1494) and a similar one in the "Abacvs" of Johannes Aventinus (Nürnberg, 1522) are the best. The latter writer, in his title page, pays tribute to Baeda in these words: *Abacvs atqve vetvstissima, vetervm latinorum per digitos manasqz numerandi* (*qui-*

netium loquendi) cosuetudo, Ex beda cū picturis & imaginibus. . . . From the 1532 edition).

A further contribution to arithmetic is the one on the study of fractions. This appears in his brief essay "De ratione vnciarvm," referring to the Roman submultiples of the *as* into *unciae*, practically the scale of twelve applied to mensuration (linear and monetary). It is particularly valuable since there is given (in the 1525 edition, Venice, which I am here consulting) the symbols for such measures as the "Deunx, vel Dextans," often puzzling to the beginner in the study of medieval documents. This edition contains also extracts from the works of M. Valerianus Probus, Petrus Diaconus and Demetrius Alabaldus—all germane to his own subject.

A man of such repute as a scholar and of prominence in the church naturally attracted the attention of the faithful in all parts of Britain. So great was his renown, even after his death, that his tomb at Jarrow became a shrine for pilgrims, urged by the belief that his relics could perform miracles in this world and could relieve souls in purgatory. Especially on the anniversaries of his death did priests and people assemble at his place of burial to watch and pray and chant the services for which he had led the singing in his monastery for many years.

In the ninth century Alcuin of York urged the monks of Northumbria to follow the path laid out by Baeda and not to forget the praise which he had received from men and the glorious reward from God. It was because of his great repute and the miracles reported by visitors to his shrine that his grave was later rifled for the purpose of carrying relics to various churches. In the eleventh century one Elfred (Alfred), a priest in the cathedral at Durham, announced himself as commissioned by heaven to collect bones from the graves of saints and expose them to the faithful. In this way it is asserted that he stole the bones of Baeda from Jarrow and carried them to Durham. The story is too long for repetition here, but to-day the traveler may see in the Galilee chapel of the noble cathedral of that city a slab bearing the inscription, "Hâc sunt in fossâ Bædæ venerabilis ossa."

As to the term "Venerable," this can hardly have been given him on account of his great age, since he died at or about the age of sixty-three. It is more probable that it was a title used somewhat as in the case of archdeacons in the Church of England to-day and for another purpose in the Church of Rome.

The portrait accompanying this sketch is from an engraving of the eighteenth or the nineteenth century and can hardly lay claim to any antiquity. In those professing to be authentic, however, there is a general resemblance which suggests an earlier drawing from which all were taken.

For those who care to follow more at length the contributions of Bede to science, reference may be made to his collected works, edited by J. A. Giles (twelve volumes, 1843–44), and the essay prefixed to his "Historia Ecclesiastica" by Charles Plummer (Oxford, 1896).

Baeda's works were published several times in the sixteenth century as in Basel (1521, 1563), the 1563 edition appearing in eight volumes bound in four. The first of these volumes contains "De Arithmeticis nvmeris liber," chiefly devoted to an extensive table of products; "De Arithmeticis proportionibvs"; "De ratione calcvli," dealing with Roman money; "De loqvela per gestvm digitorvm, et temporvm ratione"; "De ratione vnciarvm" and a treatise on the calendar with a description on the astrolabe. There was also an edition by Noviomagus (Cologne, 1537). The "De natura Rerum" was published at Basel in 1529.

David Eugene Smith

THE TEMPLETON CROCKER PACIFIC EXPEDITION

A SYSTEMATIC investigation of the birds of the Pacific Ocean and its islands has been carried on by the American Museum of Natural History ever since 1920, when the Whitney South Sea Expedition began its fifteen-year survey of that vast area. Recently a new section, known as the Whitney Wing, has been added to the museum, and into it are being moved the study collections and offices of the Department of Birds.

Two floors in the Whitney Wing are to be devoted to exhibition, and on the second floor there will be a series of eighteen faunal habitat groups, showing scenes on a carefully selected series of islands from the American coast to New Guinea. The preparation of such exhibits involves the collecting of vegetation, samples of soil and rocks, and the sketching of landscapes, all from the exact locality to be reproduced. So when Templeton Crocker of San Francisco offered to place his elegant schooner yacht *Zaca* at the services of the American Museum for a scientific cruise in the Pacific, he provided the ideal opportunity to secure the materials needed for some of these bird groups.

The sites chosen for the first four groups were in the Marquesas Islands, the Tuamotu Archipelago, the Bird Islands of Peru and the Galápagos Islands. So widely spaced are these localities that many other islands could be visited along the way.

The Museum's Department of Anthropology has also been conducting a survey in the Pacific—that of its human inhabitants, especially the Polynesians. Dr. Harry L. Shapiro, associate curator of physical anthropology, who had already made five visits to Oceania, was therefore invited by Mr. Crocker to join the party, so as to continue his researches in physical anthropology.

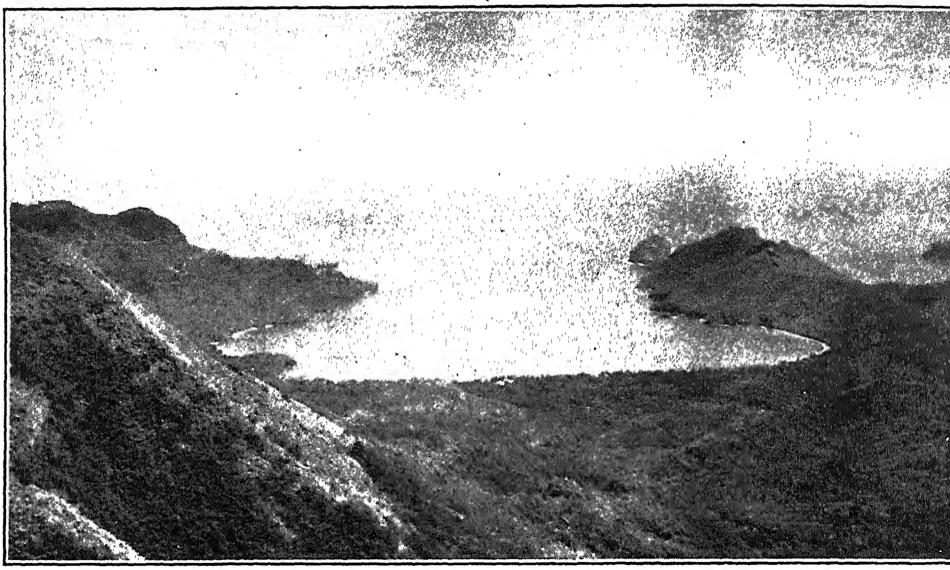
For the ornithological work Dr. Frank M. Chapman designated Francis L. Jaques, staff associate in preparation and exhibition, and myself. Mr. Crocker, leader of the expedition, engaged Maurice Willows to assist in entomological collecting, and Dr. George P. Lyman as ship's surgeon.

Sailing from San Francisco on September 15, 1934, the *Zaca* called at the port of Los Angeles and then set out for the island of Nuku Hiva in the Marquesas. On October 6 she anchored in Taio Hae Bay. After a preliminary survey, we chose for the bird group a spot on a mountain ridge overlooking Taipi Bay, made famous by Herman Melville's "Typee." The foreground will contain Hibiscus trees and ferns, with fruit pigeons, warblers and swifts, as well as white terns and noddies which come up from the sea to breed.

After Nuku Hiva, brief visits were made to the islands of Hiva Oa and Fatu Hiva; and the *Zaca* proceeded to the Tuamotu Archipelago. At Tatakoto and Hao Islands Dr. Shapiro carried on anthropological investigations, and at Hao, a rather large atoll, studies were made for the second bird group. The scene here will be a curving coral reef with palms and low trees, blue water and breakers offshore. The birds are mainly sea birds, which find safe nesting grounds on uninhabited sections of the atoll.

In November a visit was made to Tahiti, where blood-group studies were made of the native population. Next, a call was made to the Austral Islands, and Dr. Shapiro pursued his studies on Rimitara, Rurutu and Raivavae. Still more interesting was the outlying island of Rapa, remarkable for the richness of its vegetation, where the natives live under more primitive conditions than in the Austral group.

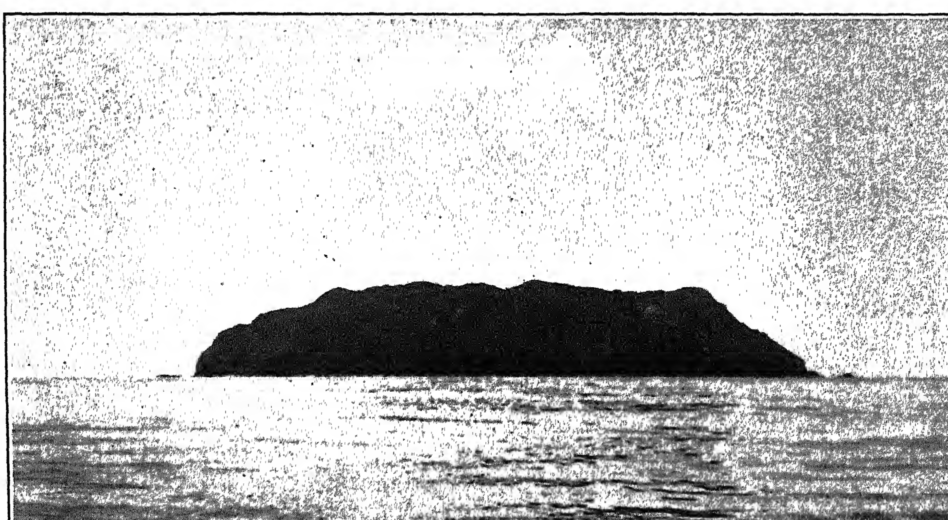
A supply of fuel had been shipped in advance to Mangareva, one of the Gambier Islands. Thence the *Zaca* set out



VIEW DOWN ON TAIO HAE BAY, NUKU HIVA, MARQUESAS.

for Pitcairn Island, which was sighted on December 22. It would be difficult to find a more hospitable folk than the couple of hundred Pitcairn inhabitants. My own impression is that of a colony of civilized white people making a living on a tiny island they love, with export trade all but impossible. As a classic example in human genetics they are of prime interest to the anthropologist, and Dr. Shapiro made the very best of his great opportunity. Dr. Lyman helped repay the kindness of the islanders by giving medical or surgical care to all who needed it.

The Pitcairn people bade us a fond



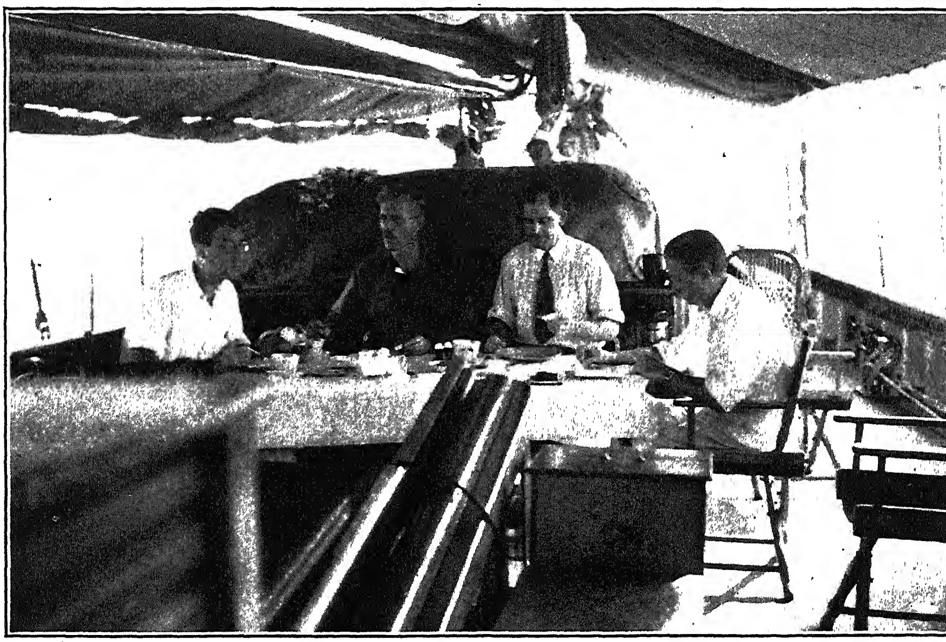
PITCAIRN ISLAND, FROM 2¼ MILES TO THE EAST.

farewell from their huge surf boats on New Year's Day, 1935, and we sailed for Ducie Island, an uninhabited atoll. Our next objective was Easter Island, justly one of the most celebrated islands in the Pacific.

This easternmost outlier of Polynesia is a little below the Tropic of Capricorn, and almost due south of Salt Lake City. The huge stone images, carved and erected by a primitive Polynesian population, aroused our warm admiration. A plaster mold was made of a typical example. The native population, still numbering some 440 souls, was studied by Dr. Shapiro. There are, unfortunately, no indigenous land birds, and, except around three rocky islets on the southwest, sea birds are not abundant.

After six days at Easter Island, we sailed on January 19 for Valparaiso. On the way a day was given to each of the Juan Fernández Islands. Now that Dr. Shapiro's work was completed, he decided to leave us and return direct from Valparaiso to New York.

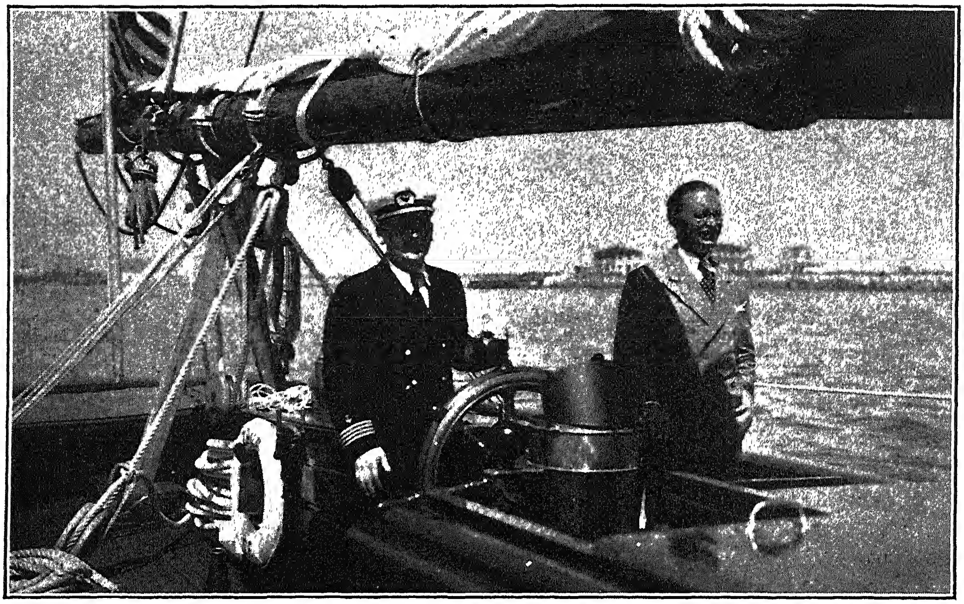
The *Zaca* sailed again on February 12, touched at Coquimbo and then left the coast to visit the remote volcanic islands of San Felix and San Ambrosio. The birds of this small uninhabited group were of special interest to Dr. Robert Cushman Murphy. We collected the seven species of marine birds which seem regularly to frequent it, and turned back toward the coast of Peru.



BREAKFAST TIME AT TERIN BAY.

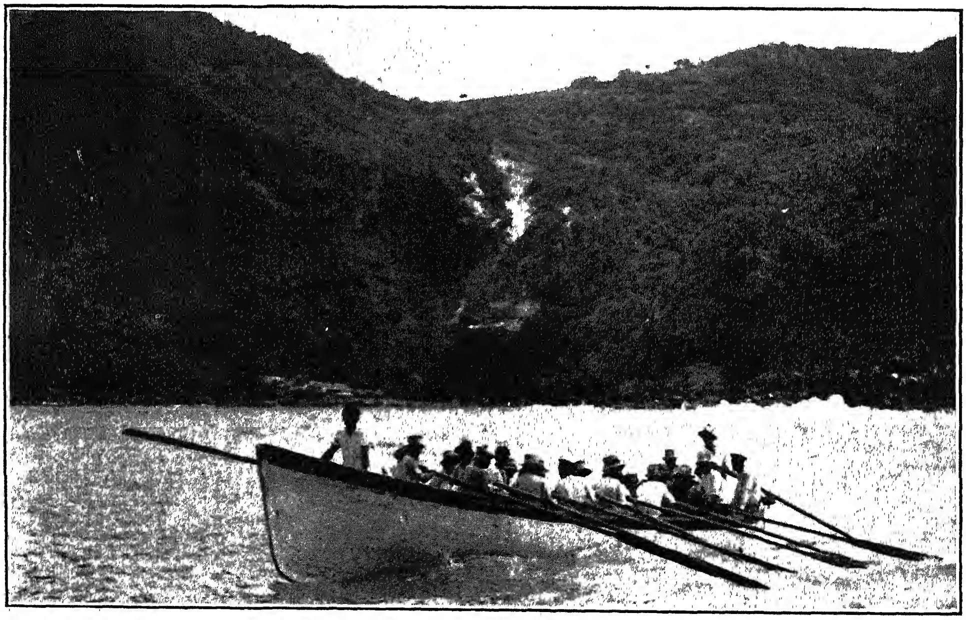
Now the bird group work began again. A spot was chosen on South Chincha Island to show the vast numbers of cormorants, boobies and pelicans which nest on these famous guano islands. Some years ago Mr. Jaques did preliminary work in this region, which has been so exhaustively studied by Dr. Murphy. So a few days sufficed to complete our work, which had the special authorization of the Peruvian government.

Next came a brief visit to Callao and Lima, then the voyage to the Galápagos.



ON THE *ZACA*, OFF CALIFORNIA.
RIGHT; TEMPLETON CROCKER. LEFT; CAPTAIN ALFRED PEDERSEN OF THE ZACA.

A visit to Tagus Cove on Albemarle Island showed that while it is an excellent spot for the study of some of the sea birds, and especially the flightless cormorant, it was not a suitable locality for our group. It is intended to show the indigenous land birds of the archipelago, the dove, hawk, cuckoo, mocking bird and



ONE OF THE SURF-BOATS AT PITCAIRN ISLAND.

finches of the *Geospiza* group, rather than the marine species.

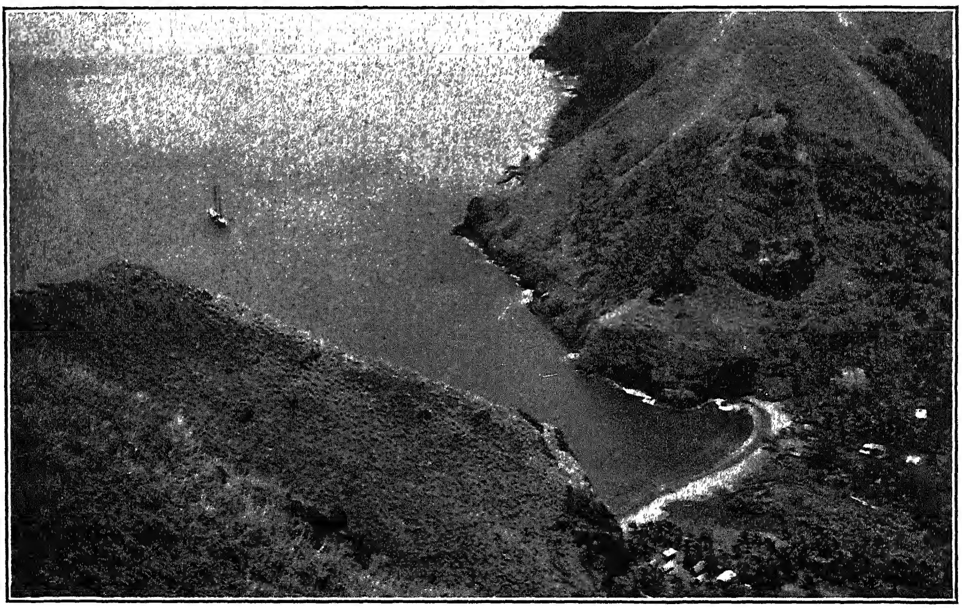
So the *Zaca* took us around the north end of Albemarle, to James Island, and then on to the more central island of Indefatigable. Here land birds occur in some abundance, and our studies were made at Conway Bay during a period of nearly two weeks. This was in March, a hot, rainy month, when the vegetation is at its best, and many of the smaller birds are nesting. Before we left the Galápagos for Panama, a morning was spent amid the nesting frigate-birds, boobies and fork-tailed gulls on Tower Island.

On the dock at Balboa on April 1 stood Dr. Frank M. Chapman, who had come over from his "Tropical Air Castle" to welcome Mr. Crocker and assistants in the American Museum.

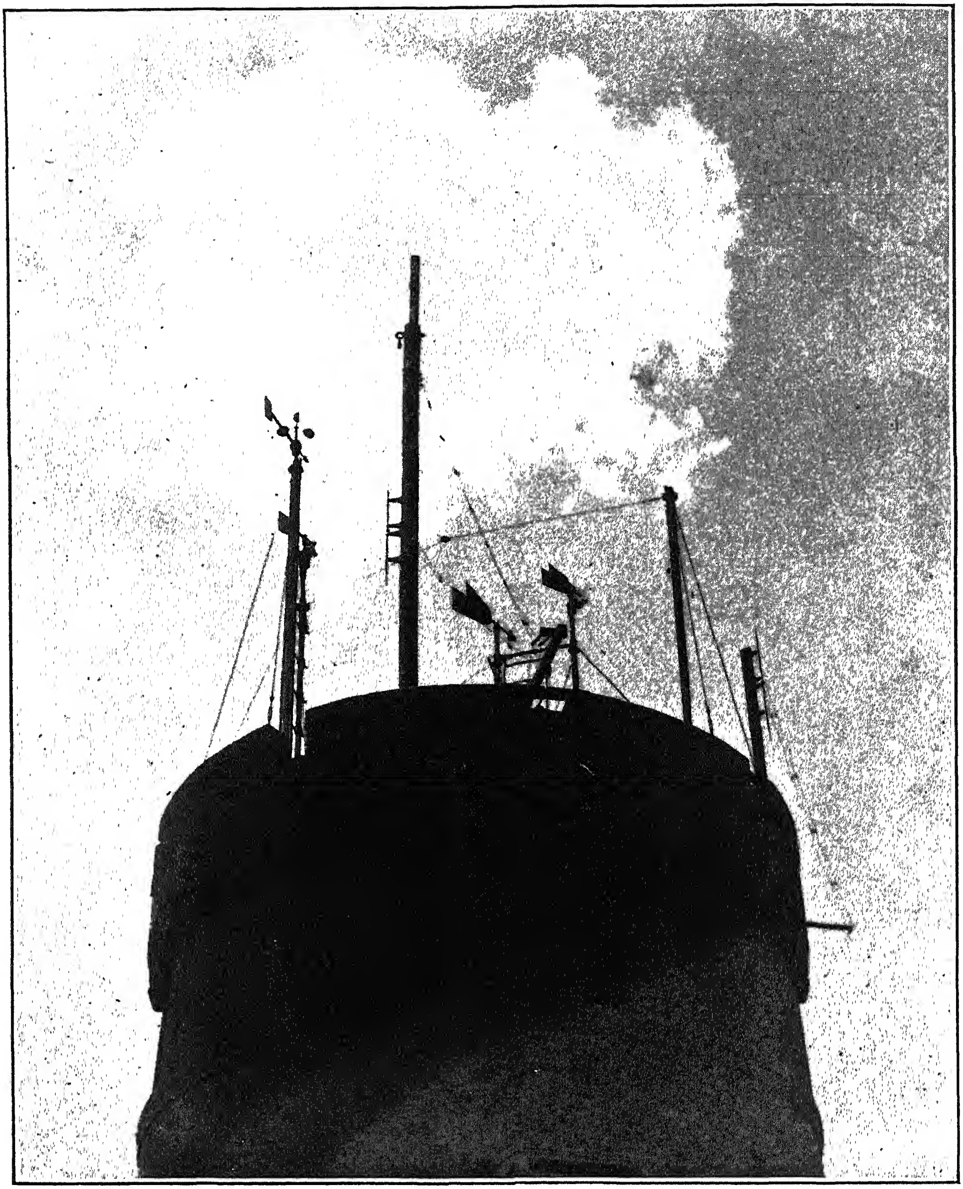
The results of our expedition include not only the anthropological data, materials for the bird groups and the numerous and admirable paintings by Mr. Jaques, but also photographs numbering over 1,500 and very many specimens gathered here and there along the way. A rich collection of marine invertebrates, fishes and algae was made personally by Mr. Crocker. His series of flying fishes, large and small, is especially remarkable. He and Mr. Willows secured numbers of insects from many of the islands. Then there are also the anthropometric series, blood-groupings and skeletal material from many of the islands, and 435 dried plants.

These collections are being divided between the American Museum, the California Academy and the New York Botanical Garden. I scarcely need add how greatly indebted we feel to Templeton Crocker, whose distinguished patronage has thus promoted scientific research in the Pacific, as well as the educational purposes of the new Whitney Hall.

JAMES P. CHAPIN



VIEW OF THE BAY OF THE VIRGINS.
FATU HIVA ISLAND, MARQUESAS, FROM A NEARBY HILL WITH ZACA AT ANCHOR.



THE BLUE HILL OBSERVATORY TOWER

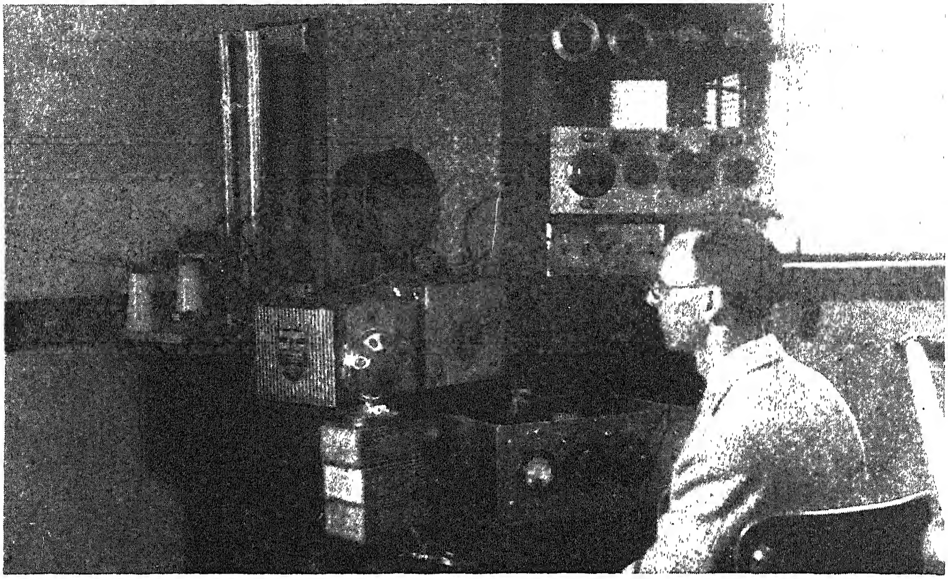
SHOWING THE 2½- AND 5-METER RADIO ANTENNAE.

SHORT-WAVE RADIO EXPERIMENTS AT THE BLUE HILL OBSERVATORY OF HARVARD COLLEGE

When Hertz began his radio experiments he chose to work with the very short waves, but as these waves appeared to have no important commercial application, later studies were directed to developing the long waves, and in general the history of radio shows progress from the longer waves, first used by Marconi to span the Atlantic, to waves of shorter and shorter length, until to-day waves of a few centimeters in length have been produced in the laboratory, linking together the short-wave portion of the radio spectrum and the long-wave end of the light spectrum. In the early days of radio communication waves as long as eighteen thousand meters were used to cover great distances and those shorter than two hundred meters were considered valueless. As experience was gained with these shorter waves, however, it appeared that with very low power it was possible to signal over thousands of miles, due to the fact that these signals were reflected back to the surface of the earth by the high ionized region known as the Kennelly-Heaviside layer. As the length of radio waves is decreased to about seven meters they cease to be reflected back by this layer, and it was assumed that there was nothing to cause them to bend around the earth, with the result that they would be lost in space and not heard at distant points. Waves shorter than seven meters would then be limited to signaling between points which were intervisible, and no variations in the signal strength would be expected.

Although short waves have been made experimentally for some years it is only recently that systematic study of the ultra-high frequencies has been carried on. When the Mt. Washington Observatory was established in 1932, on the summit of Mt. Washington, in New Hampshire, it was decided to make use of five-meter radio waves for communication purposes. It soon proved that these signals could be heard at relatively great distances, and during the winter equipment was installed at the Blue Hill Observatory with which communication is maintained with the mountain at practically all times. By means of a tone signal which is sent out at regular intervals from Blue Hill it is possible to measure the intensity of the signal at distant points and, beginning in 1932, such measurements were made at Mt. Washington, and later at other points. These distant points are below the direct optical line of sight, and Mt. Washington is one hundred and forty-two miles from Blue Hill. It was thus clear that such radio signals were able to bend in some manner and it was also found that, instead of remaining at a steady level at all times, the signals rose and fell, showing certain regular periodicities. Later on, automatic photographic recording equipment was installed at several of the observing points so that more continuous records could be kept. As a result of these measurements a well-defined diurnal change in signal was found, with a high level during the night, maxima in the morning and evening and a minimum near noon, also a probable seasonal variation, with best transmission during the summer. Certain periods are also characterized by a good level of signals, while at other times the signals may be poor for days at a time.

Atmospheric conditions during such periods of transmission suggest that exceptionally good reception of short-wave signals is associated with temperature inversions in the atmosphere. The improvement in reception may be due to the increased refraction of radio waves in the atmosphere under these conditions. This refraction of radio waves, when added to the normal bending which the waves undergo by diffraction in pass-



BLUE HILL OBSERVATORY RADIO EQUIPMENT.

THE 2½-METER TRANSMITTER IS AT THE LEFT; THE 5-METER TRANSMITTER AND RECEIVER CAN BE SEEN TO THE RIGHT; WITH THE AUTHOR IN THE FOREGROUND.

ing over hills, may well account for the occasional long-distance reception of ultra-high frequency signals.

During the past year experiments have been begun with even shorter waves, and at present communication is also possible over the long-distance circuits from Blue Hill on a wave of two and a half meters. These signals show even greater variations than those experienced on five meters, but are still useful for communication. Signals have been received over a few miles on a wave of one and a quarter meters. A fascinating field of research is opened up in these new regions, both in the systematic study of their behavior and also in the development of the technique of generating them.

Experience with the short waves has indicated some interesting new applications of them, among which is their use for sending back radio signals from free meteorological sounding balloons. An ascent into the stratosphere in a manned balloon is an expensive and dangerous undertaking. It is now proposed to make more general use of ultra-high frequency radio to send us back indication of weather conditions in this region, otherwise so inaccessible. Very small and light transmitters are being developed as well as directive receiving systems to aid in plotting the position of the balloon. Thus radio may play an important new part in the future of meteorological study.

ARTHUR EDWARD BENT
BLUE HILL OBSERVATORY,
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THE BEGINNINGS OF TIME-MEASUREMENT AND THE ORIGINS OF OUR CALENDAR[1]

By Professor JAMES HENRY BREASTED

DIRECTOR OF THE ORIENTAL INSTITUTE OF THE UNIVERSITY OF CHICAGO

INTRODUCTION

THE processes of matter seem to be the most tangible yardstick which we can apply to that mysterious flow which we call time. But the processes of matter are sublimely indifferent to the insignificant time frontiers erected by man's petty scientific terminology. As if in ridicule of such barriers raised by the children of time, the operations of the universe cross and recross the tiny areas which man has staked out. We are like some frontiersman in the night holding up a torch over a dark stream and imagining that the circle of its hurrying current revealed by the torchlight is all there is to the stream, while there may be Great Lakes above and a thundering Niagara below.

In this brief discussion of a vast subject let me make it clear that I am not dealing with any philosophical conceptions of time or its nature. I am merely endeavoring to present a sketch of some historical aspects of man's notions of time, by a study of the earliest sources of information available, with the purpose of disclosing especially the earliest known methods of time-measurement and the origins of our calendar.

[1] Lecture before New York University, given on May 16, 1935, The James Arthur Annual Lectureship on "Time and its Mysteries."

DISCONTINUOUS TIME

Modern science has so long been dealing with time as something in *continuous* flow that we accept this conception as a matter of course. This notion of time, however, as uninterrupted duration, in ceaseless, ever-continuing flow, was the final result of ages of human effort to deal with it, and did not arise until an advanced stage of civilization. An American Indian, before he was touched by civilization, would have told you that he was "fifty winters" old, or a younger native would have said that his age was "twenty snows." He thus measured time in disconnected fragments, and throughout the globe that has been the only conception of time discernible by primitive men. Some of these time fragments are fixed seasons in the early man's folk-calendar. Among certain Swedish peasants even at the present day a birthday may fall at the "rye harvest" or at the "potato harvest." A Palestinian peasant may fix the date when a note falls due, not at the end of a continuous series of months, but at the next ripening of the fakûs, a kind of cucumber. Convenient fractions of time may be designated as so many *nights*. In English we still have in common use the period "fortnight," an abbreviation of "fourteen nights." Somewhat less

common is the term, "sennight," for "seven nights." This use of nights as a series of disconnected time fragments, still current in English, is of course a survival from primitive usage, like our own North American Indian's measurement of a short journey to a mountain visible on the horizon as "so many sleeps." For a longer journey, however, to the sea far behind the mountain, the Indian would say, "so many moons."

For ages the primitive man had no conception of time, but merely of a series of disconnected units of time, what modern investigation calls "discontinuous time." The short period during which the moon disappears is so brief that a succession of moons was not broken up into disjointed links, and a series of moons therefore gave the early man his longest uninterrupted flow of time. The moon thus became the first continuous time-measurer for periods of time within the year. Almost everywhere the primitive woman knows that, ten moons (that is about nine months) after her periods have stopped, her child will be born. That measurement of the length of pregnancy is one of the oldest continuous time units on record; but it fell short of a year by almost three more moons. The process of linking together the disconnected time units to form a year and thus build up a calendar was an achievement belonging to an advanced stage of civilization.

The Luni-Solar Year

The cycle which we call a year was of course early observed by primitive man. The changing phases of the face of nature could not fail to attract his attention nor could he fail to notice that certain of these phases recurred with great regularity. On some of them he was dependent for sustenance and life itself. Every day there impinged upon him some aspect of the natural world, of sky and earth in a sweepingly wide range, from the far-off celestial bodies above to the changing life below, of trees and plants, cattle and birds and insects, and the sacred observances of man himself, based to no small extent upon occurrences in the natural world. While he had noted these recurrences for ages, the early man made no effort to determine the number of days in the cycle between any one of these events and its next recurrence, and thus to establish the length of the year. Simple as it seems to us, the conception of the year, the length of its duration and the mere arithmetic of counting the days which it occupied were far beyond human powers at first. What he did at first observe, however, was that the seasons recurred after an interval of about twelve moons. For ages his ideas of the length of year remained wholly vague as a group of roughly twelve moons. Gradually each moon month gained a name drawn from some event in the life of plants and animals, or some sacred observance of man himself connected with such an occurrence in nature.

The effort to fit the series of moon months into the cycle of the year was never successful. Throughout the ancient world, especially in western Asia and Greece, man struggled with the practical problem of the incommensurability of the length of the year and the moon month. We are accustomed to say that the Greeks were the first people to gain complete intellectual emancipation, but in the measurement of time their men of science suffered under such complete intellectual subjection to inherited tradition in the use of the moon month as a subdivision of the year that they continued to use a year divided into months, of which there were twelve and a fraction in each year. They resorted to elaborate devices for making a term of years equal to a given number of integral moon months. They devised a cycle of eight years with three intercalated

moon months or, more accurately, of nineteen years with seven intercalated moon months. The engineer Meton, who adopted the nineteen-year cycle from acquaintance with Babylonian astronomy, knew well enough that his elaborate cyclic scheme did not match exactly with the observed new moons. In view of this fact it is most extraordinary that the Greeks never possessed the intellectual emancipation to reject the moon entirely from their calendar and adopt a conventional month dictated by social needs. They knew of the Egyptian calendar, and in the middle of the fifth century B.C. Herodotus praises it, evidently under the impression that its year of 365 days was correct. But the Greeks had inherited their lunar calendar from Babylonia, and it was so firmly entrenched in their life, beliefs and customs that they were never able to cast it off.

From the earliest times the lunar month dominated the calendar of western Asia, where it arose at least as early as the fourth thousand years B.C. under the leadership of Babylonian civilization. The Babylonian kings at first adopted an erratic method of intercalated months inserted at irregular intervals, by royal command whenever the king noticed, as Hammurabi says in one of his letters, that "the year hath a deficiency." He then ordered the insertion of an intercalary month. It was not until 528 B.C. under Persian sovereignty that Babylonia adopted a fixed lunar cycle for the insertion of intercalated months at regular intervals. It was this cyclic system which was introduced from Babylonia by the Greeks. At the very time when the Greeks were thus fastening upon themselves the intolerable inconvenience of a lunar calendar they might have observed that Darius the Great, the ablest administrator of the ancient world, had introduced into the Persian Empire the Egyptian calendar, which disregarded the moon month. The long-established habits of the Western Asiatic peoples, however, and especially the eventual triumph of Islam, resulted in the universal restoration of the lunar calendar. The disharmony between the lunar and the solar year was carried to the absurdest conceivable extreme by Mohammed, who was so densely ignorant of the nature of the calendrical problem that in the Koran he actually forbade the insertion of intercalary months. The so-called "lunar year" of 354 days, being eleven days shorter than the solar year, revolves entirely around the solar year in a little over thirty-three years, that is, about three times in every century. A monthly observance like Ramadhân, the month of fasting, if it is now in June, will be in April six years from now. It is now (1935) 1,313 years since the Hijra, or the Hegira, the beginning of the Moslem era, but each of our centuries contains over 103 of the shorter Moslem lunar years. In 1,313 of our Gregorian years there are about forty-one more Moslem years, so that the Moslem era of the Hijra is now in the year 1354 (that is, 1,313 plus forty-one).

The authorities of the Jewish church in the Orient avoided such absurdity, and employed intercalation to keep their lunar calendar at least roughly within the framework of the solar year. All western Asia therefore still continues to suffer under the inconvenience of the most primitive form of time-measurement, the lunar calendar.

The Stellar Year

The Egyptians were the only ancient people who clearly recognized the cause of that inconvenience and possessed the courage and intellectual freedom to remove it. The total incommensurability of the solar or stellar year and the so-called "lunar year" could be discovered only after determination of the length of the solar or stellar year, and recognition

of the fact that there is no such thing as a "lunar year."

The determination of the length of the year, together with the discovery that it had a fixed length, was a long slow process lying far back in prehistoric ages. As we shall see, it is an extraordinary fact that it was not the sun which first furnished early man with the length of the year. Other natural phenomena much more intimately within his circle of observation must first have revealed to him the beginning of another annual cycle. The beginning of the annual run of salmon, the blossoming of certain plants or, after the introduction of agriculture, the successive tasks of cultivation might mark the years. The peasants of Palestine call the years so many "threshing floors"; the Arabs of Lower Iraq count the years by "date harvests"; in the East Indian Archipelago the years are counted by "rice harvests." The conception of a year thus arose gradually. On the East Indian Island of Bali the two monsoon seasons are each made up of a list of months which have the same names and are therefore identical for the two halves of the year. This fact shows us that the two seasons were separated from each other and the conception of the complete year cycle had not yet arisen. The process of uniting the seasons into a year was therefore a slow and gradual one. At first, as may still be observed among some surviving primitive peoples, there arose a list of moon months which did not fill the entire year. After those months were past, before the beginning of a new year, there followed a period of indifferent length, completing the old year. This intermediate period of varying and indifferent length served to adjust the inequality between the solar year and any number of integral lunar months and brought the months into rough correspondence with the solar year. Eventually there arose a list of lunar months, twelve to thirteen in number, which were thought to fill the entire year. There is, however, no equivalence between an arbitrary series of lunar months and a solar or stellar year. Hence there really is no such thing as a "lunar year," and Mohammed's year of 354 days is a creation which corresponds to nothing in nature. Historically, the lunar month has been useful as first suggesting a convenient series of twelve subdivisions of the year, but beyond that fact it has caused endless confusion and complication throughout human history.

The lunar month of course contributed nothing to the determination of the length of the year, and curiously enough the sun, the other great luminary, did not first enable man to discover the year and determine its length. While the sun's apparent revolutions shift their positions from season to season they nevertheless go on in an unbroken series with no beginning and no end. The sun's apparent motions therefore did not at first suggest the year cycle. It is quite evident that primitive men had very early begun to observe the stars and to notice the reappearance of a prominent star or group of stars after it had been invisible for a time. Such a reappearance was an event which cut sharply into the sequence of events in the stellar sky, and easily came to mark the beginning of the year. In several regions of South America the word for Pleiades is the same as the word for year. In the eighth century B.C. Hesiod places his agricultural program in the calendar by observing the return of the Pleiades in May. If the Greeks had only continued to build up their calendar on this stellar observation, they might have saved themselves centuries of difficulty and complication with their inherited Babylonian lunar calendar.

In prehistoric ages, many thousands of years ago, the dwellers along the Nile, the greatest river known to ancient man,

very naturally began their year with the beginning of the annual rise of the vast river, as the most important terrestrial phenomenon of which they knew and also the source of fertility on which an agricultural people depended for their very life. The four-month season of the inundation, which fructified the fields, was followed by another four-month season of planting and cultivation, and a third and final four-month season of harvest. This year of three four-month seasons was obviously one which arose out of the life of an agricultural people. It was essentially an agricultural folk-calendar, and its months were obviously moon-months in the beginning and doubtless continued to be so for thousands of years.

But, like primitive man everywhere, these earliest known agricultural peasants along the Nile had begun at a very remote date to scan the heavens and observe the stars, probably some thousands of years before Hesiod was doing the same in the eighth century B.C. There is probably no other country in which Sirius, the Dog Star, the brightest of the so-called fixed stars, is such a brilliant and noticeable spectacle in the evening sky. In the latitude of Lower Egypt Sirius rises about four minutes earlier every day. Every fifteen days he rises about an hour earlier, so that eventually he rises in full daylight, when he is of course entirely invisible. After a period of some months of invisibility, this brilliant and beautiful star suddenly reappears on the eastern horizon at sunrise. This "heliacal" rising of Sirius, as it is called, is a noticeable and sharply defined event. By a remarkable coincidence this heliacal rising occurs very near the time of the beginning of the inundation. In antiquity this date was the nineteenth of July. By a lucky accident, the beginning of the year at the advent of the inundation in the enormously ancient peasant calendar was thus fixed at the moment of an important astronomical event. The basis of the calendar which was to become that of the civilized world was therefore a stellar, not a solar year.

The 360-Day Year

It is important to notice that the earliest observances of the heliacal rising of Sirius must have been very primitive in character, as we shall later illustrate. Persistent dust storms, such as we experience to-day, desert fogs and mists or sometimes storm clouds must have made the determination of the exact day when Sirius reappeared on the eastern horizon not a little uncertain. It is certain that the length of the stellar year as measured by successive sunrise reappearances of Sirius was at first roughly established by the Egyptians as 360 days. As early as the fourth thousand-years B.C., that is, well back of 3000 B.C. we find this 360-day year divided into thirty-six decads of ten days each, for grouping the constellations along the celestial equator. This appearance of a circle of thirty-six decads in the fourth millennium B.C. is highly significant. It is certainly the oldest appearance of a circle of 360 divisions. The Sumerian sexagesimal system, in which sixty appears as a numerical unit (called *šuššu*), is without doubt enormously old; and in all probability arose from the length of the year—360 days—by dividing it into six parts. It seems probable, as concluded by Zimmern, that *šuššu*, the Babylonian word for sixty, means "one sixth." In both Babylonia and Egypt the convenient and basic number (360), of fundamental importance in the division of the circle and therefore in geography, astronomy and time-measurement, had its origin in the number of days in the year in the earliest known form of the calendar. While its use seems to be older in Egypt than in Babylonia, there is no way to determine with

certainty that we owe it exclusively to either of these two countries. A common origin older than either is possible.

The 365-Day Year

The Egyptians found their primitive 360-day year very convenient in business and social life, and it therefore survived far down into the historic age; but as their observations of the heliacal rising of Sirius accumulated, they finally discovered that the year, as they thought, contained 365 days. We are in a position to determine the date when they took administrative action to make this discovery of the approximate length of the year practically effective. In the year 4236 B.C., as determined by Borchardt, some now unknown ruler of prehistoric Egypt, without doubt residing in Heliopolis, introduced a calendar year of 365 days. It began with the heliacal rising of Sirius, that is, on the nineteenth of July. This calendar contained the three old agricultural peasant seasons: the inundation, the cultivation and the harvest, each season containing four months. The epoch-making importance of this calendar lies in the fact that these twelve months were entirely divorced from any connection with the moon, so that the deviser of the calendar could make each month thirty days long. By the addition of five feast days at the end of the year, this year of twelve thirty-day months or 360 days became the earliest known and practically convenient calendar of 365 days.

Earliest Fixed Date in History

The only celestial phenomenon to which any attention was paid in devising this calendar was the establishment of the beginning of the year at the first heliacal rising of Sirius. In other words, the mind that devised this calendar put social and economic needs first and divorced the calendar from celestial processes. It is of the greatest interest to observe that this calendar inevitably soon parted company with Sirius, for, owing to the fact that the stellar year is about a quarter of a day longer than 365 days, Sirius rose a day late, every four years; that is, at the end of the fourth year after the introduction of the calendar he rose on the second day of the New Year or one day late; at the end of eight years two days late; that is, on the third day of the year; at the end of twelve years three days late; that is, on the fourth day of the year; and so on to the end of the year. The calendar-makers did not at first observe this discrepancy, and when they finally did become aware of it, they held to the supremacy of social considerations, and made no attempt to shift the calendar back into harmony with Sirius. Eventually, therefore, in four times 365 years, that is in 1,460 years, the Egyptian calendar revolved entirely around the celestial year. A remark by Censorinus informs us that in the year A.D. 139, Sirius rose on New Year's day, that is, New Year's day in the civil calendar of Egypt once more coincided with the heliacal rising of Sirius. It is easy to compute that the next earlier coincidence of this kind must have occurred in 1318 B.C., the next earlier in 2776, and a still earlier one in 4236 B.C. Archeological considerations forbid us to suppose that we may push back still another such period of 1,460 years. We may therefore conclude that the civil calendar of Egypt was introduced in 4236 B.C.

This date, near the middle of the forty-third century B.C., is not only the earliest fixed date in history, but also the earliest date in the intellectual history of mankind. It has been well said that "the Egyptian calendar is the greatest intellectual fact in the history of time reckoning,"[2] but it is far more than that. For the introduction of this calendar was

[2] Nilsson, "Primitive Time Reckoning," p. 280.

an intellectual feat, marking the dawn of a recognition of the supremacy of social requirements. As we have already remarked above, in divorcing this new calendar from the processes of nature, the Egyptians were recognizing for the first time a world of social needs which they placed first. It is to-day the earliest known such recognition, and the earliest dated intellectual event in human history. It ushered in the great epoch, which was in full development after 4000 B.C., when the Egyptians discerned that their once purely nature-gods, who had originally been only personifications of natural forces and natural phenomena, like the Sun-god Re, or the Vegetation-god Osiris, were gradually shifted from a world of natural processes to be arbiters in a newly discerned social arena, where moral forces were emerging. The calendar was thus the beginning of a great movement in human life which carried over the thought of man from the world of nature to the world of human life.

Egyptian Source of European Calendar

This remarkable calendar remained the exclusive possession of the Egyptians for over thirty-five hundred years after its introduction. The effort of Darius the Great to introduce it into Western Asia late in the sixth century B.C. proved unsuccessful. The Greeks, as we have seen, wasted their scientific gifts in adding one futile refinement after another to the hopelessly inconvenient and complicated Babylonian lunar calendar. Nearly four and a half centuries after the fruitless attempt of Darius, another great administrative genius gave Europe for the first time a sane calendar. In 46 B.C. Julius Caesar introduced into the Roman Empire the Egyptian calendar, with one important modification. He provided for the addition of one day to the year of 365 days once in every four years. The history of this important innovation is interesting.

The first knowledge of a year of 365 days was brought to Europe by Thales, the Ionian philosopher, who learned of it on a visit in Egypt. Curiously enough, Herodotus also learned of it there and praises it as a perfect solution of the complications due to the incommensurability of moon-month and year. Neither Thales nor Herodotus seems to have known that the year of 365 days was too short. It is obvious that the Egyptians early observed the rate at which the heliacal rise of Sirius diverged from the beginning of the calendar in their civil year, revealing to them that their 365-day year was a quarter of a day short. The extraordinary achievements of the Babylonian astronomers in the Chaldean and Persian periods included a computation of the length of the solar year by Nabu-rimannu, or Naburianos, as the Greeks called him. Not long before 500 B.C. this great astronomer calculated the length of the solar year as 365 days, six hours, fifteen minutes and forty-one seconds—a result which is only twenty-six minutes and fifty-five seconds too long. This is the earliest known close approximation to the length of the solar year.

For over a century and a half no one seems to have made any practical application of this new knowledge. It was not until the third century B.C. that the Egyptians made an effort to correct the error in the length of the year. We still possess the granite stela of Ptolemy Euergetes I, bearing his decree, dated in the year 238 B.C., which commanded that every fourth year should be one of 366 days. But the Egyptian people obstinately refused to conform to this decree, and the correction in the calendar never became effective.

In 380 B.C. the able Greek astronomer and mathematician Eudoxus visited Egypt and there learned the fact that the year was really about 365¼ days long. Then for the first time this fact became common knowledge in Europe. Some two centuries later, that is, early in the

second century B.C., the great Greek astronomer Hipparchus announced that 365¼ days was in error, that is, it was too long by one three-hundredth of a day. This error was unknown to Caesar, and we all know that for this reason in March, 1582, the Julian calendar was superseded by that of Pope Gregory.

It is evident, however, that Julius Caesar brought to Europe for the first time a sane calendar system of twelve thirty-day months. If jealous Roman emperors and other scientifically ignorant meddlers had not utterly disfigured the Egyptian calendar, we would not be calling the ninth month September (with the numeral seven), the tenth month October (with the numeral eight), the eleventh month November (with the numeral nine) and the twelfth month December (with the numeral ten)! Nor would our young people be obliged to learn and repeat a verse of poetry in order to find out how many days there are in a month.

The Week

With the introduction of the Egyptian calendar time became something in which *human* processes were, so to say, systematically staked off into annual stages and substages. These subdivisions of a calendar, particularly the shorter ones, arise only at an advanced stage of social development. The origin of the month was of course due to a celestial phenomenon, but that of the week was in origin purely human and social. A market week of three, four, five, six, eight and ten days is a calendar division of purely secular origin. It is found over practically the entire globe, where civilization has advanced sufficiently to possess arts and crafts, with exchange and commerce of a primitive kind. It is quite commonly a *rest* day on which work is forbidden. There is a universal connection between market day and religion. Among some peoples, as among the Hebrews, the religious significance of the day predominates, and the feature of rest becomes a religious mandate. For our subject, the week, whatever its origin or significance, is of slight importance, for the week has played practically no part in time-measurement.

The Day

For many reasons, which are too obvious to need enumeration, the smaller subdivision, the day, has always been of fundamental importance in the measurement of time. It is extraordinary that among the various peoples there should be such wide diversity in the understanding of just what a day is. Modern astronomers consider a day as beginning at midday and therefore lasting from midday to midday. The peoples having a lunar calendar conceive the day as lasting from evening to evening; while in modern life the day begins at midnight and lasts from midnight to midnight, a point of practical convenience as marking the transition from one day to the next, and ignoring the night. This conception of a twenty-four-hour day is not even yet in our railroad time-tables. We really have two periods of twelve hours each, very inconveniently distinguished in our time-tables by leaded or black-faced type suggesting darkness at *mid-day,* which we sagaciously shift to light-faced type, suggesting daylight at *mid-night!* The modern languages possess no word for the twenty-four-hour day. Only the ancient Greeks seem to have possessed such a word in their convenient *νυχθήμερον*. The Egyptians began the day at dawn, which seems the natural thing for an originally peasant people to do. The practise of beginning the day at dawn was adopted by Europe at an early date, and continued down into medieval times. It was the introduction of the striking clock, in the fourteenth century of our era, which shifted the beginning of the day to midnight.

There was as much diversity in the *length* of the day as in the time of its beginning. In view of the varying length of the *daylight*-day no one finds anything strange about a flexible or elastic day. It is in the subdivisions of the day that we have come to expect constant length. Division of the day into hours is unknown to primitive peoples. The Greeks and Romans in the West and the Chinese in the East had originally no hour divisions of the day, which they all received from the Near East. The Greeks were accustomed to identify times of day by such cumbrous devices as "the time of full market," which was the middle of the forenoon. Subdivision of the daylight-day into twelve parts was introduced into Egyptian life at a very early date. We find it in the Pyramid Texts, and this means that it was practised in the fourth millennium B.C., that is, before 3000 and possibly as early as 3500 B.C. The Egyptian was interested in a convenient division of his day into twelve parts, but he was not concerned that these twelve parts should be of constant length. The reason for this probably lay in his early timepieces, as we shall see. The Babylonians also possessed a subdivision of the day at an early date, but it divided the daylight-day into six parts, and the night into six more. The modern habit of translating the Babylonian term *bêru* (formerly read *kasbu*) for this part by "double hour" is of course very misleading, if not entirely incorrect.

The Earliest Timepieces

Sun-Clocks

What type of time-measuring devices the Egyptians at first employed we do not know. The earliest such devices that have survived in Egypt date from the fifteenth century B.C. They were of two kinds and measured time either by the observation of celestial processes or by the employment of physical processes under artificially arranged terrestrial conditions. The celestial processes employed for time-measurement were the movements of the sun and the stars. In a country as nearly cloudless as Egypt the observation of the sun was a valuable means of determining time. The Egyptians therefore devised the earliest known sun-clock. In its oldest form it was an instrument shaped like a T-square laid down horizontally. The cross-head of the T-square was laid toward the east in the forenoon, and was sufficiently thick to form a barrier casting a shadow along the much longer stem, which was graduated with marks for six hours. At dawn the shadow of the cross-head cast westward by the sun just clearing the eastern horizon covered the whole length of the graduated scale out to the mark of the first hour at the end. As the sun climbed the eastern sky the shadow shortened until at noon it disappeared at the mark of the sixth hour. The instrument was then turned around with the cross-head of the T-square toward the west, so that the lengthening shadow cast by the afternoon sun marched back along the hour marks to the twelfth, identical with the first hour at the end of the scale.

Such a system of determining time by measuring the length of the shadow cast by the sun was of course continually subject to alteration caused by the seasonal changes in the position of the sun. At first these Egyptian sun-clocks were fitted to the length of the day at the equinoxes and were not correct at any other season. It would have required some generations of experience in instrument making to have enabled even the supreme skill of the Egyptian craftsmen to produce a shadow clock of this type, which would have indicated correct time.

The sun-clock makers tried to adapt their instruments to seasonal changes by using a *series* of hour scales, eventually *seven* in number. This showed progress

and improvement; but such a sun-clock was not an accurate timepiece.

Moreover, the Egyptian did not yet know enough of the motions of the earth and sun nor of the mathematics involved to discern the underlying principles which should have governed the construction of his sun-clock, and especially the arrangement of the hour scale for the different times of day and for the changing seasons of the year. He further improved his clock by employing only a narrow beam of sunlight and shortening the graduated scale by raising it to an oblique angle of some forty-five degrees above horizontal. While improving the accuracy of the device, these changes also made it small enough to be portable. It was indeed the earliest known portable timepiece. It was equipped with a plummet so that it might be kept in the plane of the horizon; but little could be claimed for its accuracy. The great Egyptian conqueror Thutmose III refers to the hour indicated by the sun's shadow at a critical moment while on his first campaign in Asia. It must have been, therefore, that he carried with him into Asia some form of sun-clock. It is probably only a coincidence that the oldest sun-clock we possess bears the name of this king (fifteenth century B.C.).

Another form of sun-clock employed the *direction* of the sun's shadow, rather than its length. Lines diverging from a center were marked on a plane surface, which might be either vertical or horizontal, and these enabled the observer to determine the different hours, which were marked next to the lines. This form of instrument was simply a sundial, and evidently the ancestor of our own sundials. Again the Egyptian makers did not understand the rather complicated problems involved in making such a device indicate time accurately. It is interesting to note that one of these Egyptian sundials bearing the name of the Pharaoh Merneptah of the thirteenth century B.C. has been discovered in Palestine.

Stellar Clocks

We have seen that the Egyptians began their year by stellar observation. They must have begun very early the determination of the hour also by observation of the stars. The word "hour" was written in hieroglyphic in the earlier period of Egyptian writing, with a *star* after it as the so-called "determinative." In order to use the night-sky as a stellar clock it was necessary that the observer should build up a list of important stars together with the times at which they crossed his meridian at different seasons of the year. If complete for all the seasons such a list would enable the Egyptian at any time of year to observe the night-sky and determine the hour. He seems to have devised a primitive type of "transit instrument" intended to enable an observer to determine the instant when a given star crossed his meridian. Naively simple and undeveloped, this instrument was employed as the observer sat cross-legged on the flat roof of a building, supposably often a temple. Opposite him at the other end of the building squatted his assistant facing him, and both of them exactly on the same meridian which was probably marked on the roof. We know that the Egyptian engineers and surveyors of five thousand years ago could lay down a meridian with a good deal of accuracy. The oldest pyramid, that of King Snefru at Medum, was oriented in the thirtieth century B.C. with surprising accuracy. Our astronomical observer, seated on a meridian line which we may regard as fairly accurate, peeped through the forked top of a palm branch which he held in his hand as a kind of sighting staff, and sighted through the slot in the top of the palm branch at the stars in the opposite northern sky over the head of the squatting assistant. A star rising to culmination

over the assistant's "crown," that is, the exact center of his head, might be over his "left eye," over his "left ear" or over his "left shoulder." These positions were determined with some precision by the use of a plummet. As the observer looked through the slot in his sighting staff, he held his plummet well out in front of the staff, so that the plumb-line at a point near its top cut through the star he was observing, and at a lower point just above the weight the plumb-line also cut through some part of the head or figure of the observer's assistant squatting at the other end of the building. The plumb-line then cut through one shoulder, one eye or one ear of the assistant. Thereupon the observer could wait until, as he followed the star with his plumb-line past the ear and the eye, the plumb-line finally cut through the top or crown of the head. The star was then in culmination and was crossing the observer's meridian. This was the most important function of the device. It was chiefly a transit instrument and as such is the oldest known astronomical instrument. It was called in Egyptian a *mrḫ · t* or *merkhet,* meaning "instrument for knowing," to which we should add the word "hour." As an "instrument for knowing the hour" is of course a timepiece, we may regard *merkhet* as the earliest known word for "clock."

It is obvious, as Borchardt has observed, that these meridian observations themselves would necessarily have had to be accompanied by some kind of time record such as is furnished to-day by the astronomer's clock. He has supposed that the Egyptian observer originally compiled a time-table of hours when important stars crossed his meridian or occupied definable positions near it, which could be stated in terms of the head and shoulders of the observer's squatting vis-à-vis. Two such star-tables have been preserved, pictured in the tombs of Ramses VI and Ramses IX at Luxor, that is, about 1150 and 1120 B.C. The positions of the stars are given at twenty-four different times of the year, that is, twice a month, on the first and the fifteenth. These tables very much need detailed study by an experienced astronomer. Thus far the only star identifiable is Sirius, and his only determinable position is his culmination. These position-tables must have been accompanied by time-tables, probably on papyrus, which now seem to have perished.

Water-Clocks

Evidently some kind of timepiece was employed in the compilation of these time-tables, otherwise the culminations observed would not have furnished any indications of time. Borchardt has demonstrated that the Egyptian water-clock, the famous clepsydra, or "water-stealer," as the Greeks called it, was used for measurement of the hours of the *night* and has therefore concluded, with much probability, that it was a clepsydra which was used to furnish the time data which transformed the night-sky for the Egyptian into a vast stellar clock.

There were two types of the clepsydra, one which we may call an *outflow* clock, and the other an *inflow* clock, according as the water flowed out of, or into the graduated vessel serving as the clock. In both these forms of clock the principle was essentially the same. Of the inflow type, which seems to have been the more accurate system only two specimens are known to me. Thirteen examples of the outflow type have been preserved in whole or in part. The oldest of them bears the name of Amenhotep III, and therefore dates from around 1400 B.C. We know, however, of a maker of such clocks, who lived 150 years earlier, about 1550 B.C. This man, whose name was Amenemhet, is the earliest known astronomer, physicist and clock-maker in the history of science. He left a brief

autobiography engraved on the wall of his tomb-chapel in the great cemetery of Egyptian Thebes, which lies opposite modern Luxor. Amenemhet proudly tells us that he lived and served at the court of the first three pharaohs of the eighteenth dynasty. He takes evident satisfaction in relating that he made a clock for Amenhotep I, that is, some time in the middle of the sixteenth century B.C. He avers that he had read all the existent literature on the subject, as a modern scientist might do. Whether in the course of this reading, or as a result of his own researches, does not appear, but our clock-maker tells us of his observation that the winter night was fourteen hours long, while the night of the harvest season (summer) was twelve hours long. He mentions that he constructed his clock in accordance with the fact that he had noted an increase in the length of the nights from month to month and also a decrease from month to month. He then goes on to say: "I made a clock (*mrḫy·t*) computed for the year . . . [it was correct (?)] at the going in of the harvest season (summer) in the cultivation season (winter), at the union (?) of the moon with its seasons. Every hour was at its time."

Externally this clock, built by Amenemhet for the king of Egypt, was of unique interest, for it was the earliest timepiece of which we have any record, fitted with tiny statuette figures so devised that they appeared at the proper intervals and indicated the hours. Unfortunately, the text of Amenemhet's autobiography is much damaged and very fragmentary. His description of these mechanical arrangements informs us that "Nekhbet (the Moon-goddess) walked at the same time with Re (the Sun-god) [while she extended the symbols of life and prosperity] which were in her hand, to the nostrils of his majesty. Then she went down (meaning she dropped out of sight) . . . ," and unfortunately at this point there is a bad gap in the text, after which we find the words: "[and Re] rejoiced when he saw these goddesses ascending and descending before him." As Sethe has noticed, "these goddesses" are obviously the well-known hour-goddesses, each personifying an hour. Amenemhet had evidently arranged small figures of these goddesses, each of whom came into view at the proper point of time, thus by her appearance announcing the hour. It must be borne in mind that these figures belonged to a water-clock and not to a mechanical clock of cog-wheels and gears, for such mechanical developments were devices entirely unknown in the sixteenth century B.C. They did not come in until the Hellenistic Age, after Alexander the Great. We may suppose, with some probability, judging from the verbs of motion employed in the description, that the moving figures were attached to floats on the surface of the water in the clock, and that they therefore moved up and down with the changing level of the water. It must have been a pleasing and picturesque timepiece which Amenemhet devised, and he tells us with evident satisfaction that it pleased the king. It was the earliest of these ingenious artistic mechanical clocks of which we see the first reaching Europe when Saladin sent such an elaborate timepiece to the Emperor Frederick II in A.D. 1232.

Amenemhet's fragmentary description of his elaborate clock, combined with all the data now observable from an examination of the surviving Egyptian water-clocks, especially the oldest of the outflow clocks, does not reassure us regarding our ancient astronomer's ability to construct an accurate timepiece. In the simplest terms this device consisted of a water vessel, with a hole in or near the bottom for the escape of the water and a graduated scale of hours engraved on the inside from the top to a point near the bottom. To a modern scientist it

would be axiomatic that the sides of the water vessel should be vertical and parallel; or, stated more simply, the vessel should be a cylinder. To our surprise, however, we find that all the Egyptian water-clocks are inverted truncated cones. The only reason I can suggest for this unsuitable form is that its flare made the scale of hours on the sloping inside walls of the vessel more accessible and more legible. Of the complications which this form added, the Egyptian's limited knowledge of hydraulics left him wholly unaware. If the column of water had been cylindrical, its rate of escape would have been greatest when the column was highest, that is, when the greatest pressure was being exerted on the water escaping at the vent. This variation in the rate was obviously increased by giving the vessel a flare, so that the upper half contained a much greater volume of water than the lower half.

The Hour

Now the function of such a clock was to divide the night into twelve equal parts. There was, however, no sufficient method for securing a uniform flow of water during each one of these twelve parts. The hours decrease too rapidly in length from the beginning to the end of the scale of hour marks on the inside of the vessel. Only in the middle is one hour that is approximately correct. Amenemhet indicates that his clock was adjusted to show the hours for all seasons of the year. His narrative, as well as the surviving water-clocks, show that whether the night was short or long, it continued to be divided into twelve periods, that is to say, in winter each of the twelve periods of the night was longer, and during the nights of summer each of the twelve periods was shorter. In other words, the hours were not of constant length. We are accustomed to a flexible *day* of varying length, but an *hour* of elastic length is surprising to us. The scheme of marks was intended to indicate the lengths of the nights in all the different seasons. Indeed the later water-clocks provide for indicating a change in the length of every night, from night to night, and in the period around 300 B.C. these indications were essentially correct.

The Hour and the Twenty-four-Hour Day

The twenty-four-hour day, with hours of variable length, longer in the winter nights and shorter in the summer nights, or longer in the summer days, and shorter in the winter days, reached Greece with the Egyptian clocks in the time of Alexander the Great. We know that an Egyptian clock was shown to the cynic Diogenes as something unusual and curious. It passed thence to Rome, where the first sun-clock appeared in 293 B.C., having come into Italy by way of the Greek cities of Sicily. The first water-clock did not arrive in Rome until 159 B.C. It is important to notice that the Greeks and Romans both had small divisions of the day long before this. Homer knew of divisions of the night determined by observation of the constellations, and Herodotus tells of Babylonian devices for determining divisions of the day. The oldest evidence of the twelve-hour day in Greece is in the Homeric studies of Aristotle, where he refers to "the twelve parts of the night" (τῆς νυκτὸς αἱ δώδεκα μοῖραι).

The Egyptian hour of varying length, which thus came into Europe with the twenty-four-hour day, remained in use nearly down to the end of the Middle Ages. The Babylonian *bêru* (formerly *kasbu*), a period of one sixth of day or night, was of fixed length, and may eventually have had some influence on the European hour; but the hour of fixed length did not come into general use in Europe until the fourteenth century of our era, when it was introduced by the striking clock, which inevitably gave it wide currency.

Subdivision of the Hour

We have already seen that primitive life did not possess the subdivision of the day into hours. Much less did it have any shorter divisions of time. There are of course inexact terms of no fixed significance, as we say, "the twinkling of an eye" or the German "*Augenblick.*" For a vague period of about half an hour, the natives of Madagascar say, "a rice-cooking," while for a moment they say, "the frying of a locust." The Cross River natives say, "a complete maize-roasting," for something less than a quarter of an hour. In Illinois when I was a lad, a farm-hand would facetiously indicate a moment by the phrase, "two jerks of a lamb's tail." The shortest interval of time indicated by the Egyptian was written in hieroglyphic simply by the upraised head of a hippopotamus, with a horizontal line cutting it off. This line was intended to represent the surface of the water, and the idea suggested was that of the instant of time during which the hippo cautiously thrust his head out of the water for a quick glance around and its almost instantaneous disappearance. That was the Egyptian scribe's ingenious writing of the word "instant"; but this word did not indicate a subdivision of the hour. In so far as we can discern, the hour was divided in early Christian times in Egypt, into the half, the quarter, the eighth, etc. The sexagesimal subdivisions of the hour into minutes and seconds, now customary with us, are not earlier in the Orient than about A.D. 1000, and they did not appear in the western world until the end of the Middle Ages. The source of these divisions is unknown, but it has been suspected with some probability that the Arabic astronomers applied them to the hour from the use of them in dividing the circle, in which connection they are likewise not of early oriental origin. Even Ptolemy did not divide the circle into sexagesimal degrees, although he did apply the sexigesimal divisions to the radius of his circle.

There are indications of a small division of time employed by the Egyptian surgeons at an early date (nearly five thousand years ago) for the counting of the human pulse, and it is known that Hippocrates some twenty-five centuries later was already counting the pulse. Obviously some subdivision of the hour, and some timepiece for measuring it, must have been used for this purpose. The surprisingly accurate determinations of the length of the planetary revolutions by the Chaldean astronomers must have required timepieces adapted for use in measuring fractions of time smaller than the hour. No examples of Babylonian timepieces have survived, however, and the whole matter awaits further investigation.

Eras and Periods Longer than a Year

Of periods longer than a year the primitive mind had but the vaguest conceptions. Indeed primitive men may entirely lack the *conception* of even a year. In the Philippines the Bontoc Igorots have no notion of a year. It is of course possible to count a series of years without any notion of the year itself. The Bataks of Sumatra use smallpox epidemics as marking-off periods, usually nine to twelve years in length, and a native will say that his house is "two smallpox epidemics old." The Hottentots keep records of the ages of their live stock by the number of calvings or lambings. But among people of lower intelligence there is no conception of a long period of time. A Dahomey Negro rarely knows how old he is, and we are all familiar with the old darky who has no idea of his age.

With the advance of civilization man's increasing knowledge has had a profound influence upon his conceptions of time,

and especially his discernment of ever-lengthening periods of time. The astonishingly long reigns claimed for their early rulers by the scribes of Egypt and Babylonia must have been compiled in a primitive age of naive and childish fancies, whose fantastically impossible periods could not have grown out of any just impressions of time as measured by human history. The flow of time was not at first revealed to man by the processes of nature. The erosion of a river valley and its changing contours would not be discernible, because the early observer had no knowledge of how those contours looked one thousand years earlier. But when he saw a huge pyramid with gaping holes gnawed into its flanks by the biting sand-blast which the powerful Egyptian north wind drove against it, he knew just how that pyramid slope had looked when it left the hands of the architect a thousand years earlier. Thus the slow decay of the works of man taught him what the processes of nature could not at first have revealed. Such unwritten human records in Babylonia and Egypt began to reveal to men after 3000 B.C. the slow march of time, which became more and more evident as those records gradually took written form. The earliest known annals of a nation compiled in the twenty-eighth century B.C. covered some fifteen hundred years of human history, that is, they extended from the forty-third to the twenty-eighth century B.C. The men of the Pharaoh's court, therefore, in the twenty-eighth century B.C., that is, some 4,700 years ago, could look back upon a lapse of time a little longer than that which we survey as we contemplate the period that lies between us and the so-called fall of Rome in A.D. 476. For those men time had long since ceased to be a discontinuous duration. The earliest mention of an era appears on a monument of Ramses II in the thirteenth century B.C., a monument which is dated in the year 400 of an era which had begun about 1720 B.C.

In Babylonia the cycle of nineteen years for the intercalation of the lunar months evidently discloses a conception of time as a continuous flow of duration. It was introduced in 528 B.C.

Science and the Continuous Flow of Time

It is evident that historical impressions of the long and continuous flow of time, especially for some centuries before the beginning of the Christian era, had led the men of the Hellenistic Age and the early Roman Empire to their dreams of a thousand years, which have left us the rather misleading significance of the word "millennium" as a Golden Age.

It is rather natural science than human history which has so enormously expanded our modern conception of the flow of time. About 400 B.C. the Chaldean astronomer Kidinnu, whom the Greeks called Kidenas, discovered the precession of the equinoxes, involving a cycle of twenty-six thousand years. That was the longest period revealed by the vast celestial clock for many centuries, indeed, perhaps even into modern times. It was followed by the geologists' estimates of the length of the periods required for the formation of the earth. Much more precise are their computations of the length of the much later process which has produced the present surface of the globe. In our prehistoric survey of Northeastern Africa, it has been possible to date the desiccation of North Africa in the middle of the Old Stone Age and to show that the sand dunes of Nubia, as they marched southward, left the North African coast of the Mediterranean about thirty-five thousand years ago. The computations of De Geers have shown that it is about nine thousand years since the retreating ice of the Glacial Age reached its present latitude, while the investigations of the American geologists would indicate that

the Ice Age began probably a million years ago. Such researches, especially the field investigations of our own Prehistoric Survey in Northeastern Africa, have revealed to us this imposing panorama of terrestrial processes as the vast stage where we discern earliest man emerging as the only implement-making creature, whose prehistoric life is thus disclosed interlocking with the processes of nature, which formed our globe. It is a tremendous spectacle: the geological process, marching hand in hand with the cultural advance of man.

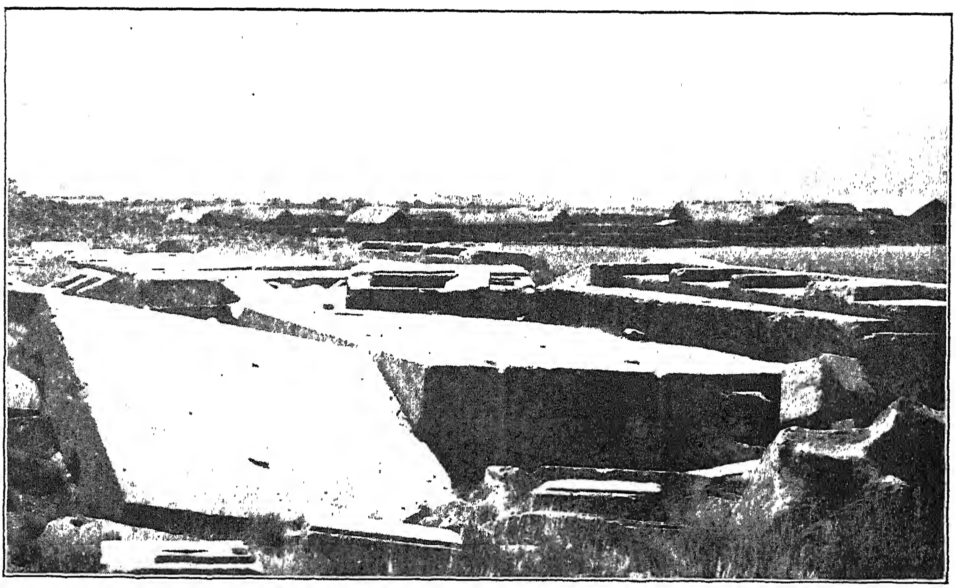
Such disclosures of the position of man in the universe form for us the culmination of man's sense of time as an historical process no longer discontinuous. We begin to feel a range of time measured by the emergence of the life of man in the universe, until we are aware that there is no time apart from man. Those celestial processes with which our knowledge of duration now begins, as they are disclosed to us in incomprehensible gulfs of millions of light years, are for us essentially timeless. We now recognize that modern investigation of early man has revealed him to us filling the gap between the incalculable duration of the celestial processes on the one hand and on the other the more comprehensible periods of the terrestrial processes that formed our globe as the home of man and led over to the historic age. Thus in vastly remote prehistoric ages, when the present surface of our globe was being fashioned by geological forces, we begin to see man, all unconscious of those forces about him, but suddenly revealed to us rising out of them and entering a realm of time, because he was, and still is, the first and only creature to be aware of time. He was its creator, the first being possessed of the ability to look back along his own trail and to recognize the point in the timeless process of the universe where the creature man entered a new and mysterious realm, which by that very fact made him the creator of a domain of time.

ARCHEOLOGICAL PERU

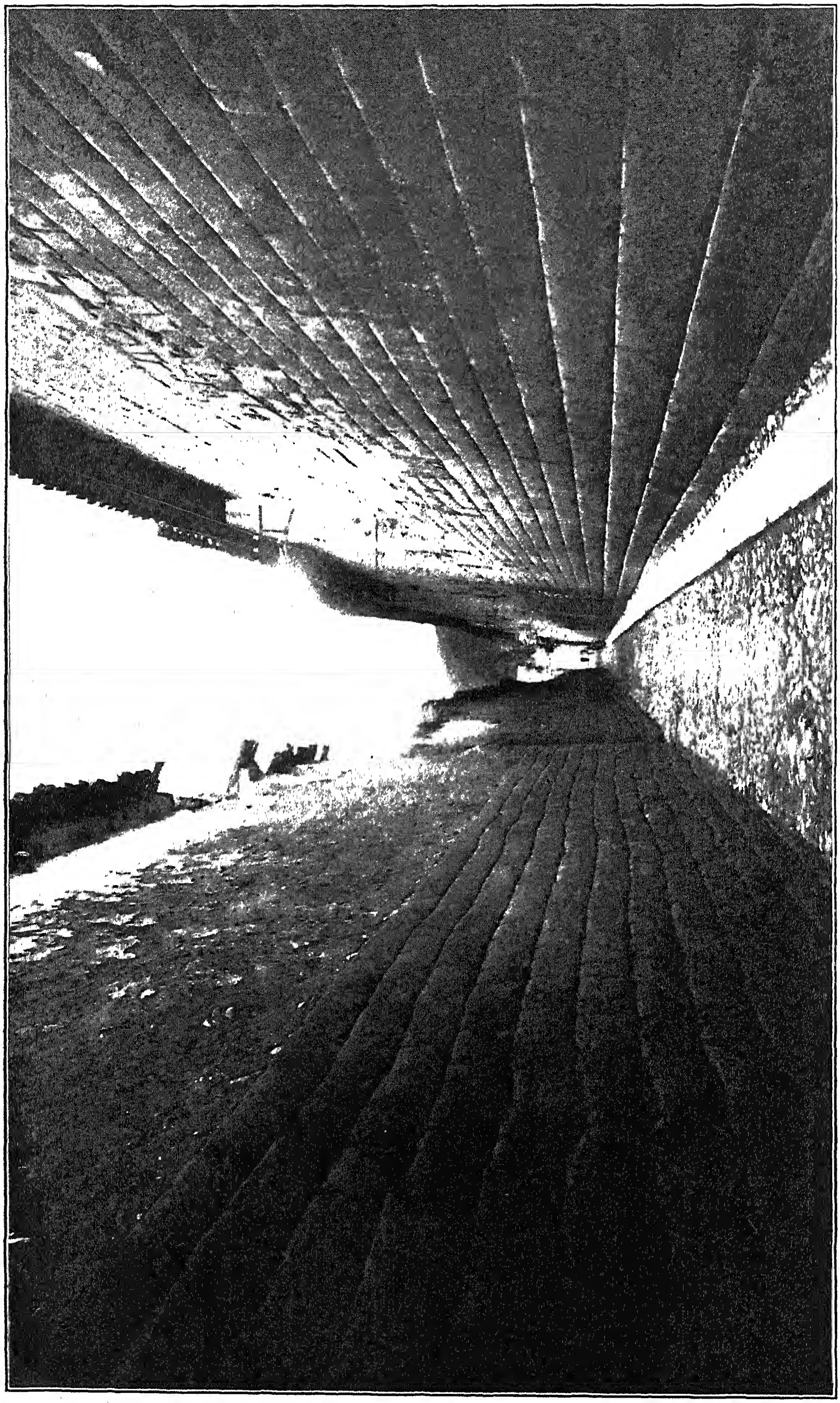
By Dr. WENDELL C. BENNETT
AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK, N. Y.

In pre-European times the western slope of the Andes was the high civilization center of South America. At the coming of the Spaniards, in 1532, the Inca empire dominated this Andean region. Their domain stretched from central Colombia through Ecuador, Peru, Bolivia and northwest Argentine to the Rio Maule in southern Chile; from the long Pacific coast line on the west across the high Andes to disappear in the Amazon jungles to the east. Just how far the Inca influence penetrated the jungles is not known, for the heavy undergrowth makes archeological investigation almost impossible, but there are suggestions that the extension may have been much greater than modern evidence has thus far revealed.

The Spaniards sought the Inca empire because of the tales of unlimited gold. The history of their conquest is well known, as well as the accounts of the quantities of gold objects found. The stories of the early historians are hard to believe, since vessels of all descriptions, ornaments, costumes, crowns, benches, even imitation flowers and stalks of corn were said to have been made of pure gold. Still, recent archeological finds show a skill and variety in the fabrication of gold which makes even the wilder tales seem reasonable. For example, one might describe a pair of gold earplugs, made of delicately incised cylinders ending in four-inch disks, with embossed figures, each holding a goblet in one hand and a flute in the other and covered with attached projecting roofs from which dangle gold hammered birds.



PUMA PUNCU, PART OF THE RUINS OF TIAHUANACO, BOLIVIA
THE STONES ONCE FORMED A FLAT PLATFORM, WITH THE ROW OF CUT STONE SEATS ALONG THE EASTERN SIDE. THE STONES WERE HELD IN POSITION WITH COPPER CRAMPS. THE FLAT STONE IN THE CENTER IS CALCULATED TO WEIGH OVER 100 TONS.



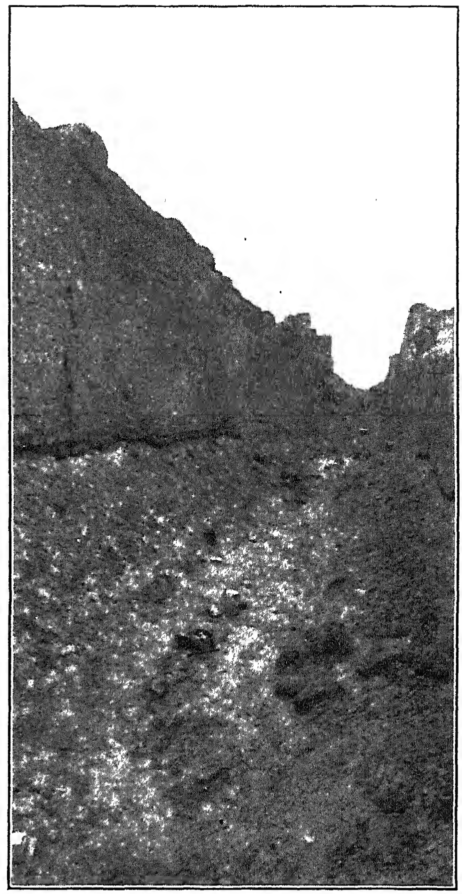
LORETO STREET IN CUZCO, PERU; A STREET IN THE ANCIENT CAPITAL OF THE INCA EMPIRE

THE STONE WALLS ON BOTH SIDES THE STREET ARE PART OF THE OLD INCA CONSTRUCTION OF SMALL BLOCKS IN COURSED MASONRY. ON THE OLD STONE WALLS THE MODERN ADOBE WALLS OF THE PRESENT INHABITANTS OF CUZCO ARE PLACED.

However, in addition to gold the Spaniards found many more things, some of economic importance and some of interest to the curious, but all amazing enough to the observers to be faithfully recorded in the accounts of this new land. They found an extensive empire with a large, well-disciplined population. Some were trained as miners; some as metallurgists; some were special weavers; and some expert in the carving of stone. Many were laborers on farm or in town. Selected individuals were special officials. In fact, the social organization of the Incas was developed to an amazing completeness in respect to the regimentation of labor and social security to the individual. Families were organized in units of ten, each supervisor of a ten-unit was again part of a unit of ten supervisors, and so on up the great pyramidal structure to the ruling Inca whose word was authority for the whole kingdom. The system was both the strength and the weakness of this civilization: its strength, because it organized a vast empire with the maximum efficiency of the materials and the mechanisms available, for the benefit of the greatest number; its weakness, because the officials, accustomed always to receive orders, lacked experience in giving them. That this was vital in times of stress is shown by the relative ease of the Spanish conquest. With the chief gone, the system disintegrated.

Communication between various parts of the extensive region was well developed. Stone-paved roads stretched for miles between important points. Suspension bridges swung across gorges and rivers. With a relay system of trained runners a message or a small article could be delivered in remarkably short time. Sections of the paved roads still exist, passing through territories which are laboriously traveled to-day. The stone piles of the suspension bridges still mark the trails of the Incas.

The architects planned and executed complex temples, houses and forts of adobe brick, stone or combinations of the two. Ordinarily only adobe brick was used along the desert coast of Peru, where rain is not a factor of destruction, while all stone buildings were common in the rainy highlands, where stone is not only advantageous but available. Many of the Inca buildings were of rough split



A STREET IN PACHACAMAC

stone, selected and piled, and sometimes calked with clay. The true arch was not known, but a corbeled dome of projecting stones weighted down from behind was erected and covered with clay for a rainproof roof. Many of these rough-stone (*pirca*) walled ruins of forts and villages are found throughout the high-

POTTERY OF THE MIDDLE AND LATE CHIMÚ PERIOD

LEFT, TWO BOWLS ILLUSTRATING INDIANS CARRYING MUMMY-BUNDLE LITTERS; CENTER, BLACK WARE PORTRAIT JAR; A BLACK WARE, DOUBLE-WHISTLING JAR, WITH MODELED ANIMAL WHISTLE;[1] EXTREME RIGHT, A JAR REPRESENTING AN INDIAN SITTING UNDER A SHELTER.

lands and mark the advance of the Incas. However, more important buildings were made of cut and fitted stone. At first stones of different sizes were carefully hewn and planlessly fitted into a wall. Later, the stones were cut into more or less unit-sized blocks and fitted into a coursed wall. Niches were left in walls for decoration, and wedge-shaped doorways were typical. Perhaps the supreme effort of Inca construction, notable both for complexity and for fineness of workmanship, is the famous ruin of Machu Picchu, near the ancient capital, Cuzco.

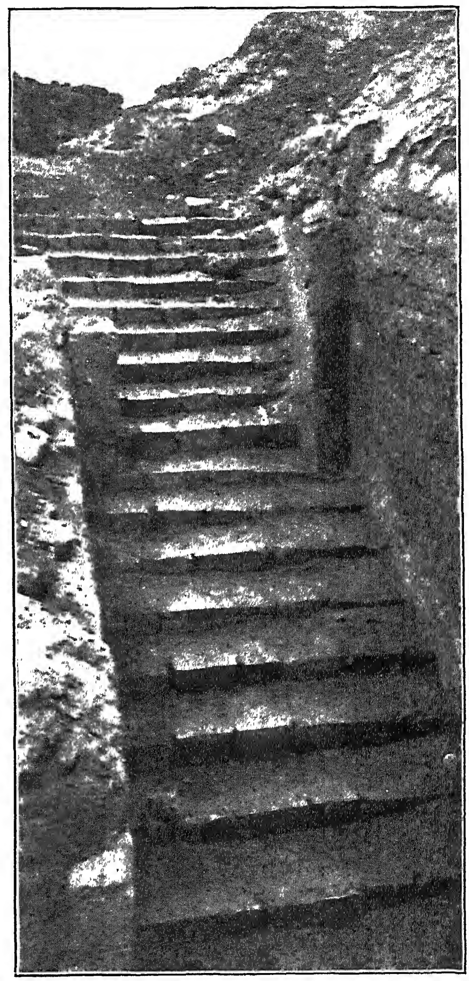
Minor arts were also emphasized in this civilization. Weaving was one of its great technical and artistic achievements. In Inca times the weaving was reduced to quantity production, the designs were geometrical and the elaborate pieces less frequent than in the pre-Inca periods to be described later. In pottery making the same tendency toward geometrical design is seen. However, the shapes of the Inca vessels are characteristic of that phase of Andean civilization and mark the presence of Inca influence wherever they are found. Typical are a pointed base, high-collared jar or aryballus, a shallow bird-handle dish, and a loop-handled bowl on a pedestal base. Besides gold, silver and copper were fabricated, and copper was alloyed with tin for tools. Bronze axes, chisels, knives and club-heads were made, as well as many copper and bronze ornaments. Stone and bone were also carved into ornaments and tools.

The accounts of the Incas are largely a matter of written history, recorded at the time and in the years that followed the conquest. Many of the recorded facts have been checked by archeologists, and numerous details have been supplied by excavators. Before the Incas, the history of Peru is largely based on archeo-

[1] Water when poured from one section to the other (accomplished by tipping the jar) forces air out through the whistle at the top and emits a mournful note.

logical reconstructions. The Incas in the eleventh century were a small tribe living in the valleys around Cuzco, Peru. Their expansion from the Cuzco area, north and south in the highlands, down to the coast of Peru, and eventually to the maximum extent of their empire, took almost four hundred years. Part of the time was consumed in building up a military and social organization that could conquer and assimilate neighboring tribes. But there were other difficulties as well. One of the major obstacles of this expansion was the varied topography of the Andean region.

The contrasting environment of coast and mountain has always been an important factor in Peruvian history. The coast of Peru is virtually a desert through which the rivers, which originate in the mountains, cut their way to the ocean and provide fertile valleys and water to an otherwise uninhabitable area. Between the river valleys are desert stretches, which, though not impassable, discourage frequent travel and are a sufficiently isolating factor to cause the development of local industries and styles in the various valleys. The mountains present a complete contrast, with high altitudes, an abundance of rainfall and deep gorges. Stretching from Bolivia to central Peru is the high plateau, or altiplano, on which lies Lake Titicaca at 12,000 feet above sea level. The plateau is cultivable, in spite of the cold nights and the absence of trees or shrubs. Isolation is largely due to distances rather than to natural obstacles. As a corollary to the contrasting coast and highland environment is a difference in materials and products. Stone is abundant and desirable for building material in the highlands, while adobe is more practical on the coast. Potatoes are the basic product of the plateau, corn of the coast. Cotton is the lowland fiber; wool the highland fiber, since it comes from the mountain llamas and vicuñas. The net result of all these environmental differences was a series of obstacles to the expanding Incas, who had to build roads where none had been before and who were forced to meet conditions to which they were not accustomed.



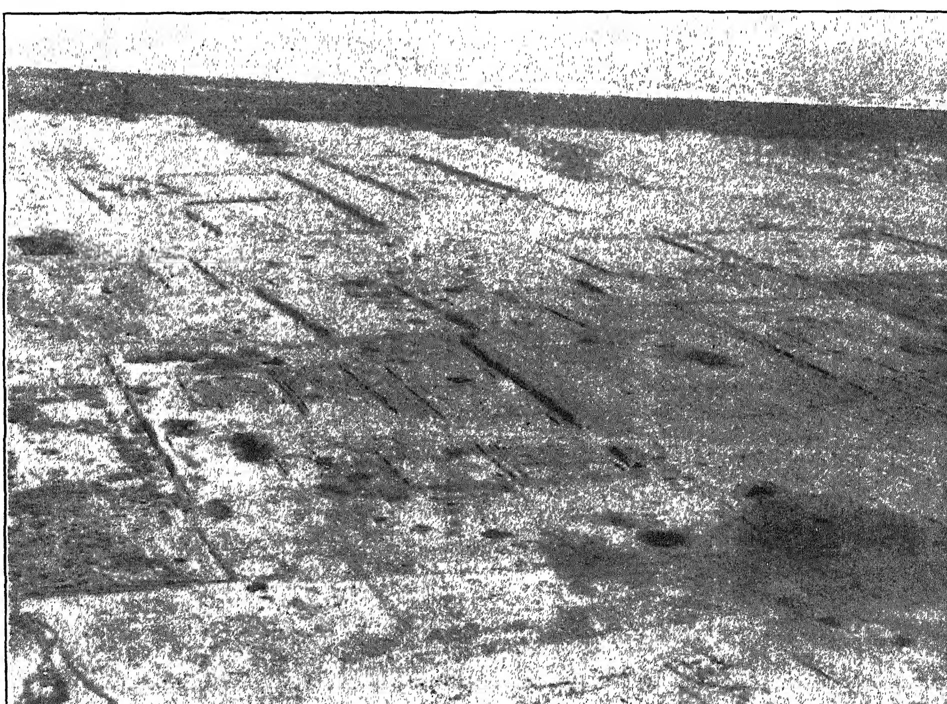
STEPS OF STONE

LEADING FROM ONE TERRACE TO ANOTHER IN THE ADOBE BRICK PYRAMID, OR FORTRESS, OF THE RUINS OF PACHACAMAC, NEAR LIMA, PERU. A PAINTED CLAY PLASTER IS SEEN COVERING THE BRICKS IN THE WALL ON THE RIGHT OF THE STEPS.

Another difficulty which the Incas faced in their expansion program was the people who already lived in these

TYPICAL INCA POTTERY

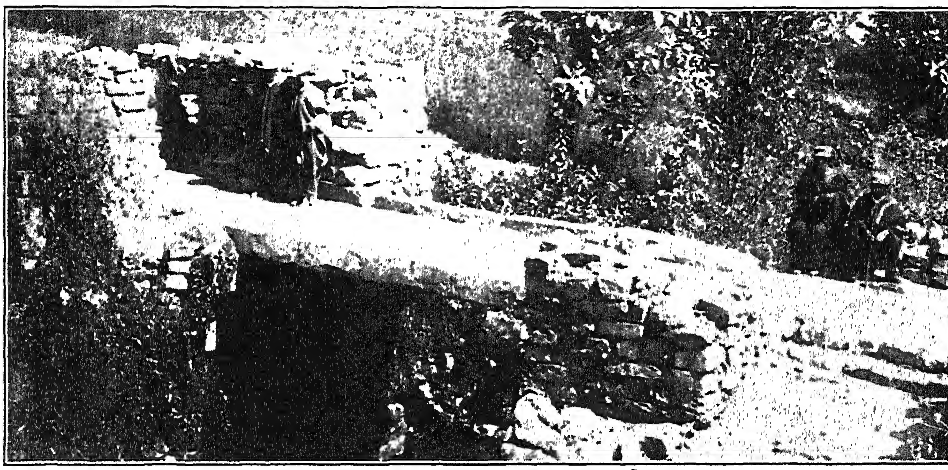
ON THE LEFT IS A SHALLOW DISH WITH BIRD HANDLE. NEXT IS THE TYPICAL POINTED BASE, ARYBALLOID JAR, PAINTED WITH GEOMETRIC DESIGN. THE WOODEN GOBLET, WITH LACQUER DESIGN, IS AN INCA ARTIFACT WHICH CONTINUED WELL INTO SPANISH TIMES. FINALLY, ON THE RIGHT, IS A LOOP-HANDLED BOWL.



A GENERAL VIEW OF THE CITY OF CHAN-CHAN

NEAR TRUJILLO, PERU. THE SURF OF THE PACIFIC IS SEEN IN THE BACKGROUND.

various regions. In Bolivia were the Aymaras or Collas, whose ancestors had developed Tiahuanaco civilization which at one time encompassed in its influence all Peru, Bolivia and parts of Chile and even Ecuador. On the northern coast of Peru were the Chancas, who constituted an additional formidable resistance to the invasion. Similar resistance was met in every region, because the Andean area was well peopled. Many of the regions which the Incas conquered had a heritage of civilization which antedated the Inca tribes by centuries. These pre-Inca civilizations have been the most fruitful fields for research of the archeologists.



AN INCA BRIDGE

PART OF A PRE-SPANISH HIGHWAY WHICH STILL SERVES THE MODERN INDIANS.

In the pre-Inca periods there is no background of traditional records; at best, the myths are sketchy and not very reliable. The archeologist must make his chronological divisions on the basis of typological differences in materials found and in the stratigraphic relation of one style to another. The basic divisions refer to the geographic environments mentioned before. On the north coast of Peru a series of adjacent valleys formed a unit with certain outstanding characteristics which could be contrasted with other regions, such as a group of valleys on the central coast or the southern coast or with various areas of the highlands. These regions were named with reference to the valleys in which the most typical material was found. Thus the northern coast forms the Chimú region; the central coast, the Rimac region, the southern coast, the Nazca region; the southern highlands (Bolivia) the Tiahuanaco region; and the central highlands, the Chavín region. Within each region, periods were distinguished chronologically into three rough categories, Early periods, Middle periods and Late periods, all preceding the final domination of the Incas.

Part of the chronological division into periods has been based on direct stratigraphy, that is, the superimposed position of one style over another. Pottery gives the clearest identification of style, although textiles, small artifacts and even buildings may serve. At Tiahuanaco, for example, one pit excavated by the author revealed a layer of Early Tiahuanaco material at a depth from about 8 to 15 feet below the surface. Above this was a layer of Classic Tiahuanaco material at from 3 to 8 feet. From the

surface to 3 feet were Decadent Tiahuanaco objects, and on the surface itself was Inca material. This type of direct stratigraphy is rare, however, and almost non-existent on the coast. Dr. Uhle found another type of direct stratigraphy on the coast at Pachacamac, where one temple had been built over an older one which had fallen into disuse. He associated graves, and the accompanying burial material, with the old temple ground surface, the old temple débris and the new temple ground surface.

Still another method of distinguishing periods and phases is that of grave association and isolation. On the premise that objects found in the same grave are contemporaneous, a group of graves can be associated by the presence of the same type of objects, as, for instance, typical Inca pottery. At the same time non-typical objects may be found in the graves which form a group, contemporaneous with but not related to Inca. In another group of graves this second class of objects may be found without the Inca associations, that is, isolated from Inca. One may deduce from this that the second class of objects existed previously and persisted into Inca times. By continuing this type of association with the second class, a third class of objects may be associated and then isolated, so that a chronology of types is set up, step by step. Obviously this method has its limitations, but in a large series of graves it has proven its merit.

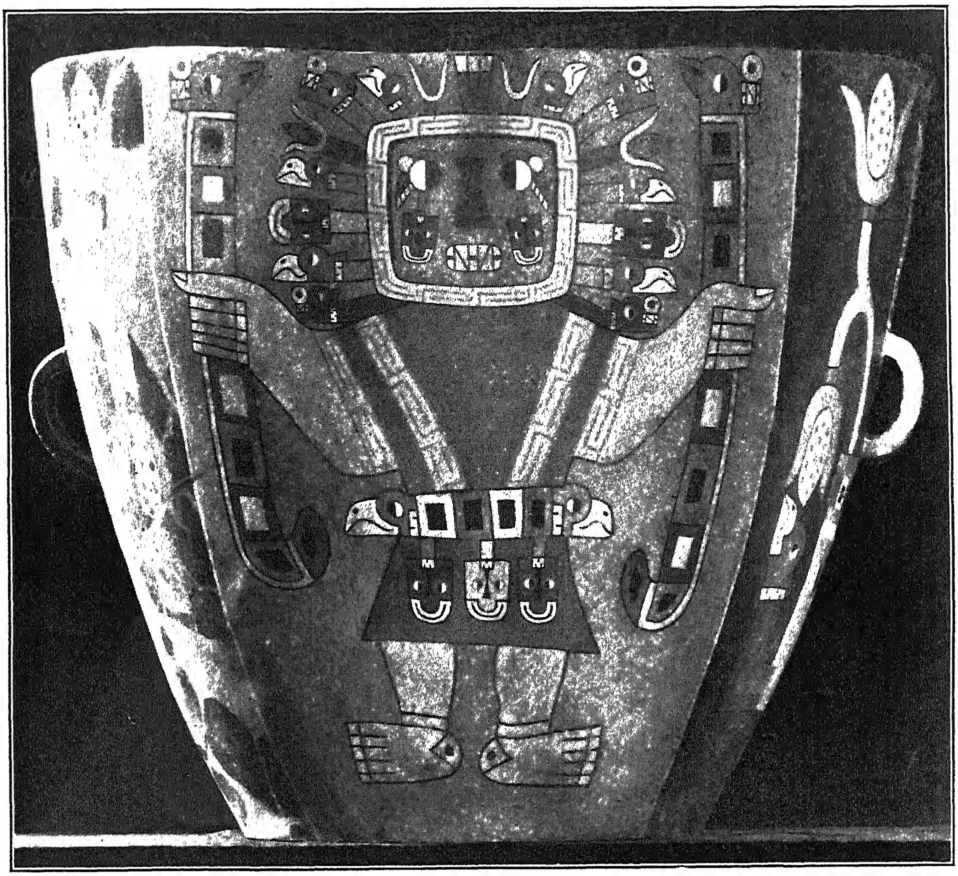
Further identification is based on association of pottery style with textile design style, and even with the painted and the arabesque reliefs on adobe walls. Certain chronological implications can be gathered from the shift in a design style, from a realistic to a stylistic, for example. In fact, there are many details in the techniques used to determine chronology. However, assuming the labor completed, for the moment, a picture of the present status of archeological history in pre-Inca times can be given.

The Early periods in the Andean region are the oldest now known, but they are not primitive in the quality of the work done. Indeed, nothing which can be identified positively with a primitive or archaic phase has been uncovered so far. The Early periods, on the whole, represent the acme of artistic and technical achievement in pottery, weaving and perhaps architecture. All Early periods, although differing in detail in the various geographical regions, tend towards realism in design style.

Early Chimú, on the north Peruvian coast, and Early Nazca on the southern Peruvian coast are both claimed, by various authors, to be the oldest known Peruvian period. Without entering this argument one may say that both are contemporaneous throughout most of their duration, which, according to Philip Ainsworth Means's chronology, is from something B.C. to about 500 A.D. Recent investigation suggests that Tiahuanaco and Chavín phases might also be contemporaneous with these coast periods.

The style of the Early Chimú period is notably one of realistic representation of contemporary life. Most of this was represented in pottery. Houses, plants, animals and scenes were modeled out of clay, as well as most remarkable and realistic portrait jars. Painted on the vessels, in reddish-brown on buff, were scenes of hunting, weaving, fishing, dancing and many other daily events. Pottery was shaped into large flaring mouth bowls or jars with double tubular spouts which curved up to meet in a single spout, known as "stirrup" spout jars. Cloth is scarcely known from this Early period, probably due to poor excavating, but skilfully fabricated gold and silver objects have been found. Large cities were built of adobe brick. Chan-Chan, the capital of the kingdom, still remains as the largest single town in the Andean archeological region.

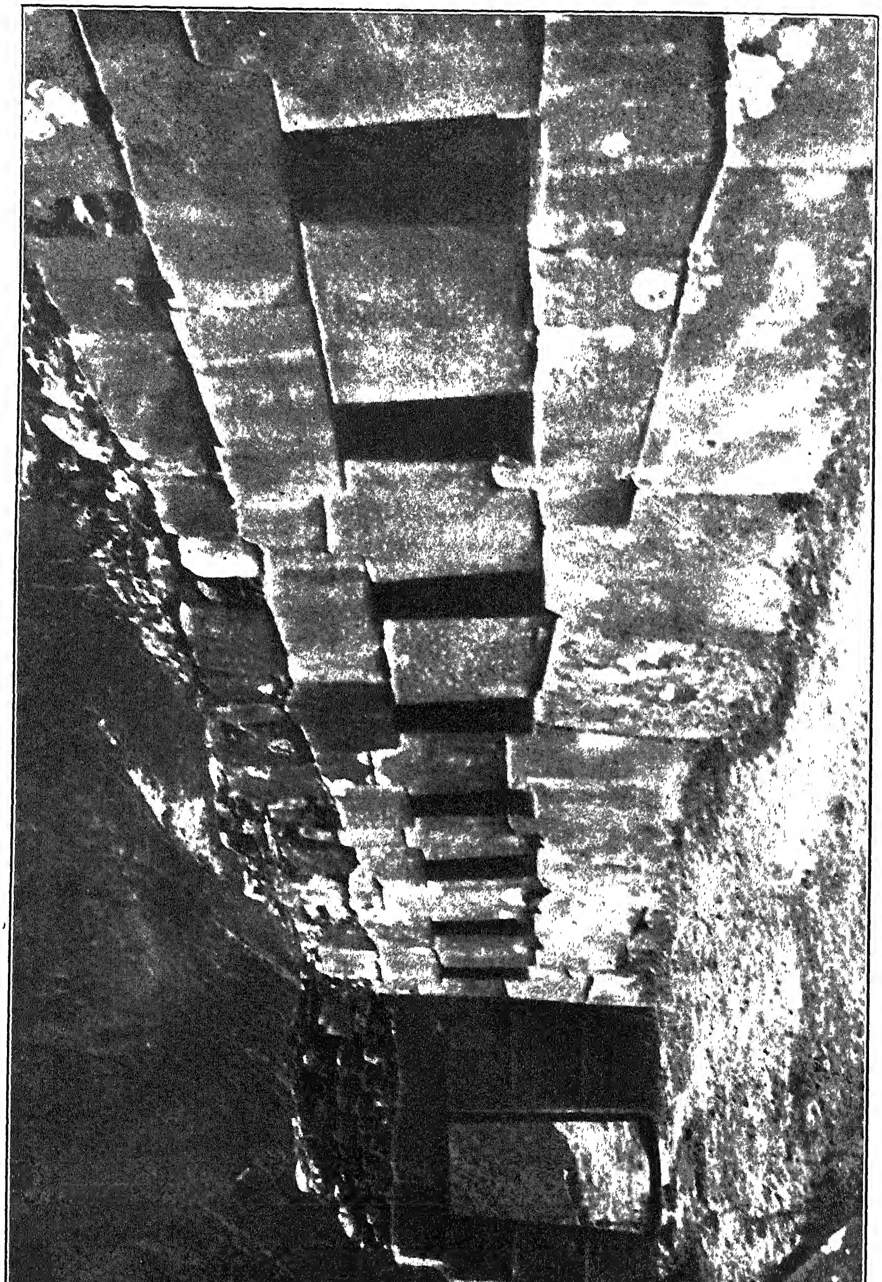
The Early Nazca style presents ceramic paintings of mythical figures in polychrome. The realism is not as pronounced in this style, particularly as representing scenes of daily life is not a part of the art. The figures of elaborate cat demons, warriors and multiple-headed gods are stylized, but still painted with an admirable freshness and variety of color. Pottery shapes are characterized by a globular bowl with a double spout connected by an arching bridge, and also a cup and tall vase with double curved sides and round bottoms. The Early Nazca period is noted for the excellent weaving, and particularly for elaborate polychrome embroideries which incorporate the same mythical god figures seen on the pottery. In many respects the variety of weaving achievements of the Early Nazca artists was not surpassed in any later period. Buildings in this period were made of adobe brick and are not particularly characteristic.



CEREMONIAL URN OF TIAHUANACO-EPIGONAL TYPE

PAINTED WITH A WARRIOR FIGURE SIMILAR TO ONE CARVED IN STONE AT TIAHUANACO ITSELF. THIS URN WAS FOUND AT NAZCA, PERU; ILLUSTRATES THE SPREAD OF HIGHLAND TIAHUANACO STYLE TO THE COAST.

The Classic Tiahuanaco in the highlands of Bolivia, around the southern end of Lake Titicaca, was probably roughly contemporaneous with the two Early periods just described. Little in-



NICHED STONE TERRACE WALL, WITH WEDGE-SHAPE INCA DOORWAY, AT THE RUINS OF OLLANTAITAMBO, NEAR CUZCO, PERU

fluence of coast style can be found in this period. In spite of that fact, trade must have been common, because Early Nazca textiles are made from both wool and cotton, the former being the hair of the llama and vicuña, both highland animals. Tiahuanaco design style depicts pumas, condors and warriors as typical motives, outlined in black and filled with white, yellow, brown and gray, all on a red slip background. The typical shapes are a flaring-sided goblet, a flaring-sided flat-bottom cup, a vase and an open wide-rim bowl. No cloth has been found in the wet highlands, but incised designs on stone statues probably were copied from contemporaneous existing textile garments. Monolithic statues are characteristic of the Tiahuanaco period. Stone, moreover, is the typical building material. Huge blocks, pillars and slabs were cut, dressed and jointed into position. Copper cramps were used to hold massive blocks in position. The achievements of the Classic Tiahuanaco period in stone cutting amazed the Incas when they discovered these ruins during their conquest of Bolivia.

The Middle periods in general mark the influence or actual domination of the highland Tiahuanaco over the coast and highlands of Peru. Almost pure Classic Tiahuanaco has been found on the coast, although in small quantities, but the applied designs, on pottery shapes already existent in the coast periods, are common. This active influence is followed by various sub-periods with local variations on the Tiahuanaco-influenced or "Epigonal" types and style. There is again regional variation, but the whole area is closely knit together by this common influence. The general tendency of design is towards stylization, away from the realism which had existed previously.

The Late periods on the coast of Peru are secondary developments in the local geographic areas. Thus, on the southern coast, the Late Nazca (or Ica) is a local development of geometric, "textile" pattern designs on new shapes, not related to their Early Nazca predecessors. On the northern coast the Late Chimú is characterized by black modeled pottery. In general, the Late periods stress geometric design. This is particularly noteworthy in textiles, where single motives are repeated again and again. Gauze, tapestries and painted cloth are common in the Late periods, while the elaborate embroideries are missing.

In this brief sketch an outline of the Inca and pre-Inca periods of Peru is presented. The beginning is not known, although an elaborate textile, ceramic and architectural art such as that found in the Early periods implies considerable time for development. Likewise, the other end of the history was cut short by the arrival of the Spaniards. What solutions the Incas might have found for their problems will never be known. The past, however, will be more clearly revealed as the quantity and quality of the archeological work increases, and then another chapter will be written on what preceded the pre-Inca periods of Peru.

THE RISE OF PHARMACOLOGY

By Dr. THEODORE KOPPANYI

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It is a remarkable fact that while the history of medicine as a whole and its preclinical and clinical branches has been adequately portrayed by many authors, the history of pharmacology proper has been entirely neglected. It has been said with some justice that the study of the historical development of a subject very often reveals its true nature. The history of pharmacology, then, will acquaint us with the task and problems of this science. It is the purpose of this review to present for the first time a brief account of the historical development of the science of drug actions. Pharmacology has allied sciences—therapeutics and materia medica—and the history of these allied sciences is indeed as old or older than civilized man.

The story of the use of medicines in the different periods of history makes a fascinating chapter in the development of knowledge. The concepts and practices of this art are deeply colored by the superstition, religion, philosophy and science of the ages. History does not record a time when man did not employ herbs and other medicinal agents for the relief of suffering. Primitive man was attracted to animate and inanimate objects of nature with characteristic shape, color, taste or odor, and attributed mysterious virtues to them and tried their efficacy in the hour of distress. His continued use of them, however, was rarely founded on any more rational basis than his use of charms, amulets, magic and sorcery for the same purpose. A superstition originating perhaps in prehistoric times but systematized and exploited in the Middle Ages was the unfortunate belief in *signaturas*. According to this creed nature pointed out the therapeutic usefulness of every substance, especially plants, by a characteristic shape, color, odor or taste (the "signatura" of the plant). For example, lemons, due to their heart-shape, are destined to be used in heart disease, the poppy plants, with their head-shaped capsule, in insanity.

Pedacius Dioscurides (middle of first century, A.D.), a physician in the service of Nero, described over six hundred plants as sources of medicines and dealt with their aromatic, oily, gummy and resinous products. He is honored as the "father of materia medica."

CLAUDIUS GALEN

(130–200) A PIONEER OF MATERIA MEDICA. FROM AN IMAGINARY PORTRAIT

Galen (131 to 201 A.D.), the first experimental physiologist, introduced a complicated system of polypharmacy. His memory survives in the term "galenicals," a term applied to vegetable remedies prepared by infusion or decoction as distinguished from drugs prepared by chemi-

SIR CHRISTOPHER WREN
(1632–1723), FRIEND OF ROBERT BOYLE

ROBERT BOYLE
THE FOUNDER OF EXPERIMENTAL PHARMACOLOGY

cal processes. Galen, however, failed to utilize his experimental physiology in the study of the vegetable drugs he used. He just missed the discovery of pharmacodynamics. This was accomplished only a few decades after William Harvey's rediscovery of physiological experimentation.

Since this essay proposes to deal with the history of pharmacodynamics, we need not consider the achievements of pharmacognosy and empirical therapeutics of the periods that have elapsed between Galen's and Harvey's times.

According to a statement in the literature the French physician Thuillier, the older, had as early as 1630 performed the experiment of feeding seeds of rye and other cultivated grasses infected with fungi (ergot). He came to the conclusion that the eating of these infected grasses was the cause of "ignis sacer" (holy fire), as ergotism was called by the medieval physicians.

It seems that the scientific study of drug action was a direct consequence of Harvey's physiological discoveries. It originated independently in England and Switzerland. It is almost certain that the first suggestion to investigate drug action in animals by the intravenous route came from the famous London architect, Sir Christopher Wren. This suggestion of a new mode of drug administration was of vast importance because of the current belief of the seventeenth century that poisons taken by mouth cause sickness and death by reflex action from the stomach. The actual experiments were carried out by Robert Boyle and Timothy Clarke in the recently founded Royal Society of London. Robert Boyle, the pioneer physicist and chemist, was apparently the first man to perform well-controlled pharmacological experiments. He administered opium and antimony compounds to dogs intravenously and studied their effects. He showed that dogs receiving opium became somnolent and shaky, whereas the animals receiving antimony compounds vomited and subsequently died.

JOHN JACOB WEPFER
(1620 TO 1695) THE ORIGINATOR OF MODERN PHARMACOLOGICAL METHODS

Thus Boyle proved that opium and antimony are active when administered by vein, and by inference he proved that these drugs when taken by mouth act after absorption into the blood stream. Boyle and his younger contemporary Clarke, who showed that oil of tobacco injected intravenously produces emesis, carried out their pioneer pharmacological researches under the auspices of the Royal Society around 1660.

In Switzerland John S. Elsholz published in 1665 a pamphlet entitled "Clysmatica nova sive ratio qua in venam sectam medicamenta immitti possunt, addita inaudita sanguinis transfusioni"—"A New Method of Clysis by Which Drugs may be Administered into a Sectioned Vein." He reported results achieved by intravenous administration of miscellaneous remedies to animals and patients.

John Jacob Wepfer (1620 to 1695) of Schaffhausen, Switzerland, was a successful physician in his native city and devoted his spare time to the study of the effects of drugs and poisons on animals with the purpose of understanding their action, of determining their toxicity and their possible clinical usefulness. Wepfer was apparently led to his investigations by the occurrence of hemlock and other poisonings that came to his attention. He published the summary of his experiments in a very remarkable treatise: "Cicutae aquaticae historia et noxae" (1679)—"History and Toxicity of the Water Hemlock." This book is the first orderly and critical presentation of pharmacological experiments on a large scale. It contains the experimental proof that water hemlock and nux vomica are convulsant poisons. Besides vegetable drugs Wepfer used antimony, mercury and arsenic preparations in his animal experiments and sought to determine the toxicity of a number of mineral drugs. On the basis of these experiments he protested against the indiscriminate use of mercury and arsenic. Some of Wepfer's experiments are models of exactitude and care, and many of his conclusions may still be accepted. His great discovery of convulsant poisons and his studies on the action of heavy metals entitle him to a distinguished place in the history of science.

Wepfer had many students and friends who collaborated with him in his animal experiments. The most outstanding of these is another Swiss physician, John Jacob Harder, a professor at Basle, who published in his "Apiarium" the results of his numerous animal experiments (he used mollusks and all classes of vertebrates except fishes) in which he investigated the action of tobacco juice and snake venoms.

For almost a century we hear nothing of experimental pharmacology. In 1755 Menghini investigated the action of camphor on animals; in 1765 Felix Fontana performed more than four thousand animal experiments endeavoring to dis-

cover the effect of snake venom on the heart and other organs. In 1776 a young German pharmacist's apprentice, Peter John Andrew Daries, published a doctor's thesis, "On Atropa Belladonna," which is perhaps the most important pharmacological contribution of the eighteenth century. Daries, while filling a prescription of a belladonna preparation, inadvertently contaminated his eye with the drug. His vision became gradually impaired and finally he became almost blind. He went to the physician originally prescribing the drug, who washed his eye and made certain observations. His vision then gradually improved and finally returned to normal. Daries then instilled the juice of the leaves and of the fruit of belladonna into eyes of cats. By carefully controlled experiments he discovered the mydriatic (pupil-dilating) action of belladonna. He even observed that the duration of mydriasis varies directly with the size of the dose.

In 1790 a pupil of the second Monro, William Alexander, published his "De partibus corporis animalis quae viribus opii parent"—"On the Parts of the Animal Body which Obey the Power of Opium." However, his experimental technique leaves a good deal to be desired.

The action of some drugs can not be fully understood through animal experimentation if the human pathological conditions which the drug alleviates or cures can not be reproduced in animals. An excellent example of such a remedial agent is digitalis. About 150 years ago there was an old woman in Shropshire who had a secret family recipe consisting of a mixture of various herbs that possessed the power of relieving dropsy more effectively than any measures known to the best medical authorities of the time. The secret of the formula was divulged to a contemporary British physician, William Withering (1741 to 1799), who in turn discovered that there was only one among the many herbs used by this woman which was responsible for the cure of dropsy. He identified this herb as the common foxglove, known to botanists as digitalis. Withering spent the next ten years studying the effects of this one herb on patients with dropsy. At the end of this period he published a monograph on treating the sick with digitalis ("Account of the Foxglove," 1785). It contained many shrewd observations on the amount of the drug that patients require, on the changes in the pulse that accompany its action and on the symptoms which patients exhibit when they are under the full effects of the drug. There can be no doubt that the treatment of dropsy after Withering's studies became immeasurably more effective than it had been before, but Withering had no more idea of how and why foxglove cured dropsy than had the old woman of Shropshire. His method was simply a glorified form of empiricism. It is for this reason that while Withering's work may be admired, it is not a milestone of critical pharmacology.

The medical profession as a whole does not seem to have paid the slightest

FREDERICK W. A. SERTÜRNER
(1783 TO 1841) THE DISCOVERER OF MORPHINE

THE STATUE OF CAVENTOU AND PELLETIER
(FROM LEFT TO RIGHT) ON THE BOULEVARD ST. MICHAEL IN PARIS. ON THE ORIGINAL STATUE THE INSCRIPTION OF THE NAMES OF PELLETIER AND CAVENTOU ARE REVERSED

attention to the struggling science of experimental pharmacology. It chose to notice, not the heroic efforts of men like Wepfer, or Daries, but the thousands of fake or absurd "remedies" listed in the vast collections of the sixteenth and seventeenth centuries, called pharmacopoeias, dispensatories and formularies. A German pharmacopoeia of the middle of the seventeenth century contained descriptions of six thousand drugs. However, in the eighteenth and early nineteenth century methods of accurate diagnosis were introduced and a new generation of scientists, the pathologists, were able to verify diagnosis by study of the organs in post-mortem examination. Then the practice that led to the employment of these six thousand remedies appeared as sheer barbarism. A new school of critical medical scientists arose, calling themselves "Therapeutic Nihilists," who expressed disbelief in the efficacy of drugs, and when a person was ill they employed either physical therapeutic measures or nature was simply allowed to take its course.

The effects of therapeutic nihilism were on the whole salutary and challenged both science and the medical profession. While therapeutic nihilism was in full swing a number of very potent drugs, the alkaloids and glucosides, were discovered which produced pronounced effects in very small doses. Thus the objection of the therapeutic nihilist against

the inefficacy of most of the crude drugs was overcome.

We recall that the great pharmacologists of the seventeenth and eighteenth century, due to the primitive state of their chemistry, were obliged to work with crude drugs. Nevertheless, they recognized the value of animal experimentation for the understanding of drug action and the determining of drug toxicity, and the necessity of animal controls before these drugs were administered to the sick. They lacked two important things, however, which were absolutely necessary for a rapid advancement of pharmacology, *i.e.,* a thorough understanding of drug action. They lacked the fine tools of chemistry necessary to extract the active principles, the real drugs, from the crude plant products, and they lacked the refined technique of modern physiology which makes it possible to determine the exact point and mode of action of drugs in fine structures of the body.

Fortunately, in the early nineteenth century both of these weapons were introduced, and thus modern pharmacodynamics was made possible. The discovery of pure principles was inaugurated by Frederick W. A. Sertürner (1783 to 1841), a German pharmacist at Einbeck, who studied the chemistry of opium from 1805 to 1817. He not only isolated morphine in crystalline form but recognized it as a salt-forming organic base, *i.e.*, he discovered the nature of alkaloids. Pelletier and Caventou, Parisian pharmacists, continued Sertürner's researches. They isolated some of our most important and widely used alkaloids: quinine, strychnine and brucine; (from 1817 to 1820) Pelletier and Magendie (1817) isolated emetine. Pelletier and Caventou were also contributors to other fields of chemistry; among others they coined the term chlorophyll. The first synthesis of an alkaloid was carried out much later by Ladenburg, who prepared coniine (1886).

In 1830 Robiquet and Boutron discovered amygdalin, and in 1837 the two great German chemists, Liebig and Wöhler, recognized in this substance a new type of compound, the glucosides.

The physiological methods necessary for the advancement of pharmacology were introduced almost simultaneously with the isolation of pure drugs. The great French vivisectors of the early nineteenth century discovered some of the most fundamental and essential methods of physiological experimentation, and thus became the founders not only of modern physiology, but of modern pharmacodynamics as well. François Magendie (1783 to 1855) investigated the action of several pure drugs by means of his newly discovered physiological methods. His researches included the study of morphine, veratrine, brucine, piperine, and emetine and also bromides and iodides. His most important discovery in pharmacology was the determination of the point of action of strychnine. Wepfer proved that nux vomica is a convul-

FRANÇOIS MAGENDIE
PIONEER OF THE EXPERIMENTAL PHARMACOLOGY OF PURE DRUGS

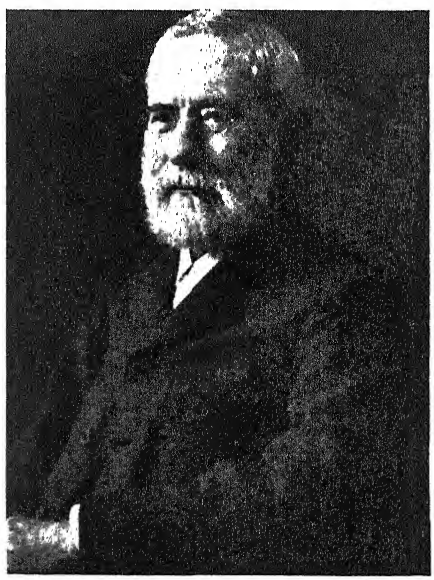
CLAUDE BERNARD
GREAT EXPERIMENTAL PHYSIOLOGIST AND PHARMACOLOGIST

sant poison. Magendie showed that the alkaloid strychnine, isolated from the crude nux vomica, is responsible for its convulsant action, and determined by brilliant experiments that the convulsions were due to stimulation of the spinal cord.

Magendie's pupil Claude Bernard (1813 to 1878), one of the greatest physiologists of all times, continued ably the pharmacologic researches of his teacher. He discovered the locus and modes of action of several opiates. He further elaborated Magendie's discovery of strychnine action by showing that the cutting of the posterior roots of the spinal nerves stopped the tetanic convulsions. Perhaps his most important contribution to pharmacology was his discovery of motor paralysis caused by injection of the arrow-poison, curare, and his experimental proof that this paralysis was brought about by the depression of the final terminations of efferent (motor) nerve fibers.

Magendie's and Bernard's pioneer work opened up the field for further researches. Their first successful followers were German pharmacologists. Rudolf Buchheim (1820 to 1879), of Dorpat, not only carried out masterly experiments on the actions of mydriatic alkaloids, thus continuing the abortive efforts of Daries, but made fundamental contributions to the knowledge of ergot, cathartics and cod liver oil. Buchheim was also the first professor of pharmacology (1846 to 1879) and founded the first independent pharmacological laboratory at Dorpat University School of Medicine.

Oswald Schmiedeberg, of Strassburg (1838 to 1921), introduced methods for the study of drug action on isolated organs, particularly on the perfused frog's heart. His researches included the study of iron compounds, also mus-

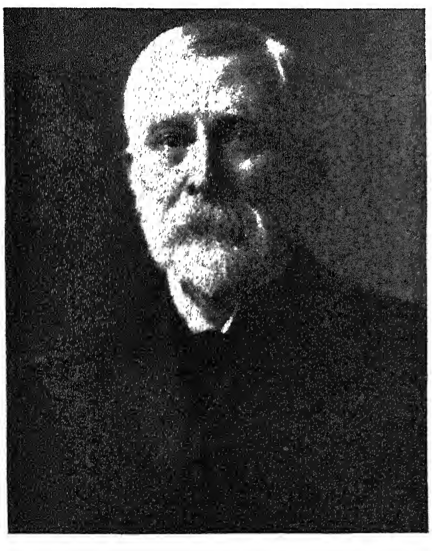


OSWALD SCHMIEDEBERG
ONE OF THE GREATEST TEACHERS OF PHARMACOLOGY

carine and digitalis. Carl Binz (1832 to 1912), of Bonn, studied the action of anesthetics, alcohol, volatile oils, quinine and arsenicals. It is interesting to recall the famous discussion between Binz and Schmiedeberg, on the mode of action of alcohol, in which Binz maintained that alcohol has a direct stimulant action, whereas Schmiedeberg asserted that alcohol has a purely depressant action and the so-called stimulant effects observed by Binz are due either to depression of the inhibitory centers in the central nervous system, or to reflex effects from the alimentary tract.

The British school of pharmacologists came into existence somewhat later, but their contributions were no less valuable. As early as 1868 Crum Brown and Fraser proved that various alkaloids possessing diverse pharmacologic actions, on combination with alkyl halides to form quaternary ammonium bases, yield substances which in almost every case paralyze motor nerve terminations in the same manner as curare. These researches proved that the addition of particular chemical groups to certain drugs may weaken or destroy or strengthen their action. Thus the first step was made towards discovering relationships between chemical constitution and pharmacologic action. Sir Thomas Richard Fraser (1841 to 1920), of Edinburgh, also discovered the cardiac action of the seeds of the African arrow poison Strophanthus and contributed to the knowledge of parasympathetic drugs.

JOHN J. ABEL
A PIONEER OF AMERICAN PHARMACOLOGY



SIR THOMAS LAUDER BRUNTON
THE DISCOVERER OF VASODILATOR DRUGS

Sir Thomas Lauder Brunton (1844 to 1916), of London, introduced nitrites as vasodilator (blood-vessel-dilating) remedies and recommended their use in hypertension and paroxysms of angina pectoris. Sir Edward Sharpey Schafer and his associates discovered, in the last decade of the nineteenth century, the

blood pressure elevating action of extracts made from the adrenal gland and from the pituitary body.

The pioneers of pharmacology in America were the great physicians and dentists who introduced ether and nitrous oxide anesthesia (Long, Wells, Jackson and Morton, 1841 to 1847). However, the founders of officially recognized pharmacology in this country are Arthur Robertson Cushny (1866 to 1926) and John Jacob Abel (1857 ——). Cushny, a pupil of Schmiedeberg, held the chair of pharmacology at the University of Michigan from 1893 to 1905. His most important contribution to pharmacology is the application of the electro-cardiogram in elucidating the action of digitalis, by which method he showed that this drug depresses the conduction of the cardiac impulse to the ventricles. Abel was appointed professor of pharmacology at the Johns Hopkins University in the same year as Cushny at Michigan. They were the first two independent professors of pharmacology in America. Abel isolated epinephrine and bufagin, and recently obtained insulin in crystalline form. His pharmacological studies on purified hormones and on phthaleins were truly epoch-making and led to important therapeutic results and diagnostic measures (kidney and liver function tests, using different phthaleins).

The trends of recent pharmacological research are along the lines of elaborating relationships between chemical structures and pharmacodynamic activity and studying the fate of the drugs in the body. They all converge toward the establishment of a strictly quantitative science of pharmacology.

THE NATURAL HISTORY OF THE BOX TURTLE

By H. A. ALLARD
U. S. DEPARTMENT OF AGRICULTURE

Conditions

The writer for several years has studied the behavior of the common box turtle under fairly natural conditions. It was necessary to confine them, but they were given the freedom of a good-sized enclosure embracing about 1,150 square feet, surrounded by two-foot chicken wire set into the ground about four inches. Although an overhanging ledge was made at the top, it may be stated that the box turtle shows no inclination to climb. Much of this area is covered with a dense growth of wild plants, blackberries and shrubs, affording an abundance of shade. Several pear, cherry, plum, mulberry trees and grapevines drop an abundance of fruit into this area, and a bearing papaw tree stood in the enclosure. Several tomato plants were grown here to furnish fruit for the turtles. A small bare clearing was maintained to afford a suitable situation for the laying of the eggs. Several good-sized cement basins were set into the soil and kept filled with clean water, to serve for bathing purposes and as drinking places.

The turtles have been kept in this area since the spring of 1932. The majority of the turtles were picked up in field and wood over a very wide area around Washington, D. C. Many had suffered severe injury in the past, presumably by automobiles on the roadway, for their shells showed extensive fractures, which had spontaneously healed, though in some instances leaving the carapace or the plastron sorely scarred with deep fissures.

It would appear that many box turtles in the free wandering life must find a rather scant supply of suitable food for considerable periods, as judged from the poor physical conditions of many met with. A number were thin and light and bore all the earmarks of a half-starved existence. The well-nourished and vigorous condition of others bespoke an acquaintance with better feeding grounds.

Under the conditions of the writer's confinement the turtles have thrived, and those held over from 1932 were in a far better state of health and nourishment at the end of the season of 1933.

Food

In the wild state box turtles eat anything they can find, including mushrooms, insects and their larval stages, earthworms, slugs, snails, dead animal matter, blackberries, strawberries, apples and other fruits. In the writer's enclosure, they ate with avidity sour cherries (Montmorency) falling from the trees, plums (Wild Goose), pears, grapes, mulberries, blackberries, papaws, tomatoes and ripe pokeberries (*Phytolacca decandra*) (August, September and October); the huge slug *Limax maximum* Linné; caterpillars of the catalpa sphinx; and the horn worms of tomato. One morning a number were seen feeding with much gusto on the putrefying carcass of a dead rat which cats had left within the enclosure. All these elements may be considered natural to their diet because they can be met with in a state of free wandering afield. In addition, their diet was supplemented with a more artificial menu, including remnants of the table, embracing potato, raw and cooked meat, bread, rinds of cantaloupe and watermelon, bananas, in truth any hodgepodge of table waste that was available. It may be said that they are especially fond of cantaloupe, eating the rinds to the last particle. They are scarcely less fond of blackberries and tomatoes, both of which turtles in the

field feed upon greedily. As a matter of fact a small tomato patch may sometimes suffer severely from their depredations.

The box turtle is by nature omnivorous in its inclinations, but from a close study of its feeding habits it is indicated that animal food is a first choice in its natural menu. Early in the season when the hunger impulse is keenest, earthworms, grubs and raw hamburg are fed upon voraciously. Of the vegetable foods, cantaloupe and blackberries head the list, followed closely by tomatoes. Although vegetable food is an important item in their natural diet, only the fleshy fruits and berries of the higher plants are eaten. At no time have the box turtles shown the slightest inclination to feed upon the succulent stems or leaves of plants growing around them.

Mating

Mating takes place soon after the turtles emerge from their winter hibernations in April. Although the egg-laying season extends only from early June until near the middle of July, mating may be observed throughout the entire summer, continuing at least into late September or October. The most active period of mating, however, occurs in springtime, preceding the egg-laying activities of midsummer. Cahn and Conder have pretty fully described the actual behavior of mating in their paper in *Copeia* (2) 86–88, 1932, and little comment need be made at the present time.

Digging the Egg-bed

Although many turtles are strictly aquatic creatures, the eggs of all must be laid and hatched under strictly terrestrial conditions in excavations in soil or sand made by the female. The box turtle attends to the deposition of her eggs with meticulous care. When a suitable spot is found, the female near sunset begins the laborious work of digging the egg-bed. Once the fore feet have been

Shallow concrete pool used for bathing and drinking.

THE HOME OF THE BABY TURTLES
LARGE HEAP OF LEAVES AND TRASH IN THE ENCLOSURE USED THROUGHOUT THE HEAT OF THE SUMMER FOR SIESTAS DURING THE HOTTER HOURS OF THE DAY. AFTER FEEDING, MANY REPAIRED IMMEDIATELY TO THE COOL DAMP RECESSES OF THIS PILE TO REST.

placed and digging has begun, these are never moved and the position of the body with respect to the eggs is not changed until the eggs are covered. The operation of digging is done entirely with the hind feet, and these are invariably alternated in the digging performance. The egg-bed or egg-cavity when completed is somewhat flask-shaped with a relatively narrow neck widening into the cavity proper which has been cut beneath the surface-layer. The soil is lifted and pushed upward and backward. The diameter and the depth of the cavity are limited by the length of the leg, and digging appears to continue until the feet can reach no farther in the deepening and lateral cutting operations.

The time required to complete the egg-cavity depends largely upon the character and firmness of the soil. In hard-packed soil, digging may require several hours of patient labor. In the writer's enclosure, digging has sometimes persisted between three and four hours before egg-laying began. Oftentimes pebbles and bits of soil are actually grasped by the toes to be lifted out of the cavity and placed to the rear. As the loose soil is removed and accumulates in a ridge behind, the turtle from time to time pushes it backward with the big, powerful hind feet.

When digging begins, the place is rarely changed or abandoned until the hole is completed. Three females only, of twenty-five observed digging, abandoned the work, one after a good-sized depression had been made; two very soon after beginning. There seemed to be no good reason to explain these behaviors. Pebbles and roots are very disconcerning to the creatures, for every effort seems to be made to excavate a

clean-cut egg-bed. In one instance the writer found a female with her egg-cavity completed, but a round pebble remained within which she could feel and push about with her feet but could not remove. She made repeated efforts with the usual alternations of the feet to grasp or to push the pebble out, but without success. The writer finally came to her assistance and when her leg was withdrawn, he removed the troublesome pebble with a stick, and perhaps obviated her abandonment of the hole after hours of hard labor; however, she was never aware of the beneficent deed.

Of sixty females observed, eggs were found at the point of the operation of covering in all but two instances. Whether the turtles never laid eggs, or whether they laid elsewhere, became frightened, left and lost their original orientation with respect to the true egg-activity will never be known.

So far as observed the egg-cavity has always been begun on rainless evenings. Light showers have intervened later, however, but the operation of digging, laying and covering did not cease. Whether a heavy downpour would cause the turtle to abandon her work is not known.

Extrusion of the Eggs and Covering

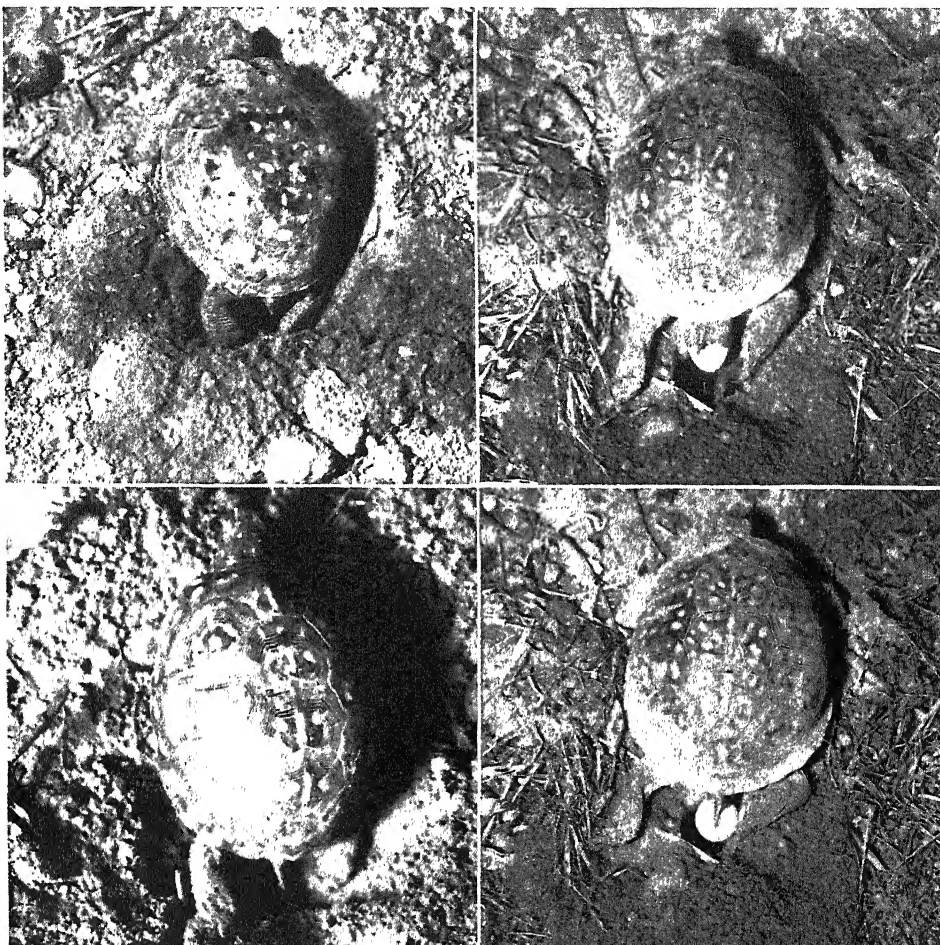
When the hole has been deepened as far as the feet can reach, the eggs one by one are dropped into the cavity. In one instance four eggs were dropped within 25 minutes; in another 6 eggs were dropped within 10 minutes; a third female dropped three eggs within five minutes. After each egg is dropped, a hind foot is inserted into the cavity and swept around as if to feel if all is well, and to place the egg as far forward as possible. If some minutes elapse before the second egg is dropped, the hind feet alternate in these movements, as in the digging operations. When the last egg has been dropped, there usually follows a brief interval of rest, with the hind foot which had been used to push and place the eggs around oftentimes left dangling into the cavity. It has been stated in the literature that the eggs are covered separately, but this procedure has not been followed in any instance in the writer's experience.

Almost invariably the first covering operation is a widely executed lateral sweep of the extended hind leg toward the hole to bring in earth. The other hind leg is then used in a similar manner. From time to time a hind foot may be inserted into the cavity to push the earth over the eggs more efficiently. From time to time wide lateral sweeps are made always with one leg to bring in the soil. Now and then, the two hind legs are extended flat and at full length backward with the toes close together, and then brought forward to the hole to sweep in earth straight from the rear where it had been pushed. It is a movement in every way comparable to that of a person crouched on the earth who would sweep in the loose sand from in front with his hands open and his fingers together. When considerable earth has been brought in upon the eggs so that to the observer they are no longer visible, or they can no longer be felt by the feet of the turtle, treading and tramping operations take place. This is always an extremely interesting and painstaking procedure and involves many nice variations in the skilful use of the toes, feet, knees and plastron in the final tamping of the soil over the eggs.

The two feet are often used in a peculiar treading operation, the knees almost or quite touching the ground. The feet are brought very close together so that the heels touch. The feet are now lifted alternately, the treading being performed practically on the tip of the toes, for the heels remain elevated. So closely are the feet brought together that she frequently steps upon her own heels, extricating her feet for each alternating tread with some difficulty. In this opera-

tion a distinct rotary motion of the feet sometimes takes place. At other times a position is taken upon the knees, so that toes, heels and knees can be combined in the treading tamping operations. At such times with the plastron held above the soil a jerky lowering of the body may be noted, as if the creature were utilizing the weight momentum of its body to supplement the simple pressing operations of the feet.

The actual covering is a long and methodically performed operation, but when it is completed there is little trace of the location of the egg-bed. In some instances the actual covering has re-



DIGGING THE NEST AND LAYING THE EGGS

Upper left. Digging the egg bed; the hind feet alone are used in this process. Lower left. A shift to the other hind leg is being made, for in the digging operations, the feet are invariably used alternately. Upper right. Second egg being deposited 8: 03 p. m. July 13, 1932. Loose earth has been pushed for some distance behind the excavated egg-bed. The usual position seems to be to recline upon one knee as shown. Lower right. Third egg just leaving the cloaca to be deposited in the egg-bed at 8: 05 p. m. July 13. The second egg no. 2 deposited at 8:03. These flashlight photographs were taken after dark by H. F. Allard, as well as the daylight pictures that follow.

quired nearly two hours before the creature was ready to walk away. The entire operation of digging the egg-bed, laying the eggs and subsequent covering has sometimes required four to five hours. In one instance, digging was performed from 6 to 9 P.M., a period of three hours; 6 eggs were laid from 9.10 to 9.20, a period of 10 minutes; covering was extended until 11.15, a period of 55 minutes.

The egg-cavity is about two and one-half inches in width and nearly two inches in depth. Neither the cavity nor the eggs are seen by the turtle, for these operations are usually performed in the darkness of night, and by the sense of touch of the hind feet alone. Under these circumstances the matter of proper orientation depends entirely upon keeping the position of the front legs rigidly fixed, and using these as pivots upon which to swing if need be, in making lateral reaches for soil with the hind legs. To demonstrate this point the writer inserted a stick very carefully under the plastron of a turtle which was covering and tamping the soil over its egg-bed, and gently swung it around into another position without disturbing it. The turtle continued its covering and treading operations, but over a spot now some distance from its egg-bed.

It has been stated in the literature that the box turtle usually deposits its eggs during the day (R. C. Rosenberger, "Interesting Facts about Turtles," *Forest and Stream,* Vol. 86, p. 764–765, 1916). This statement is completely at variance with all observations of the writer on this point. Of sixty laying females observed in 1932, 1933 and 1934,

TABLE I

DATA SHOWING NUMBER OF EGGS, FERTILITY, HATCHING, ETC., HIBERNATION, EMERGENCE AND OTHER SEASONAL BEHAVIORS FOR BOX TURTLES OBSERVED IN THE WRITER'S ENCLOSURE FOR THE YEARS 1932, 1933, 1934

	1932	1933	1934
Females laying	8	17	35
Eggs laid	33	77	119
Average number per female	4.1	4.5	4.1
Smallest laying	3	3	2
Largest laying	6	7	6
First laying	June 17	June 4	June 7
Last laying	July 13	July 4	July 6
Eggs laid in June	22–66.6 per cent.	69–89.5 per cent.	95–82.6 per cent.
Eggs laid in July	11–33.3 " "	8–10.4 " "	20–17.3 " "
Eggs without embryonic development	5–15.1 " "	14–18.1 " "	
Eggs destroyed by ants—fertility undetermined	4–12.1 " "	27–35.06" "	None
Fertile eggs, *i.e.*, with embryo	24–72.7 " "	36–46.7 " "	99–83.2 per cent.
Eggs hatching	19–79.1 " "	9–11.6 " "	22–18.4 " "
Eggs bad—condition indeterminable	no data	no data	20–16.8 " "
First emergence from hibernation in spring	1st week April	April 1 one adult " 2 adult " 2 seven (six adults, one 1932 yearling)	April 3 (one) adult " 6 (one) adult " 8 (seven) (six adults, one baby)
First observed to eat in spring	after April 20	no data	April 23
Last seen in autumn	Late November	Nov. 20 (one adult)	Dec. 2 (Several adults)

none began to dig the egg-cavity until late in the afternoon or near sunset, and with few exceptions the eggs were deposited near darkness or long after night had set in.

Number of Eggs Laid, and Fertility

The eggs of all turtles are consigned to earth and forgotten following the operation of covering. Hatching depends entirely upon the natural warmth of the soil. Tables I and II present data relative to the laying of the eggs and other seasonal data bearing on their activities.

TABLE II

Number of Eggs in Laying, and Number of Layings of Each, for 1932, 1933 and 1934

Eggs in laying	Number of layings		
	1932	1933	1934
2	None	None	4
3	2	3	4
4	4	6	10
5	1	5	7
6	1	2	4
7	None	1	None

Of 60 layings observed in 1932, 1933 and 1934, no turtle has laid less than two eggs, the average being 4.2 eggs. One turtle alone laid 7 eggs. Table II presents data relative to the number of eggs per laying, and the layings of each. There appears to be a correlation between the size of the eggs and the number, the smaller layings appearing to produce larger eggs. In some instances, where very large turtles laid only two or three eggs, these were exceptionally large. Actual weighings have shown that the eggs may range from 7 to 10 grams in weight. The largest eggs measured were three of the laying of July 6, 1934, these being 37 x 22; 38 x 22 and 36 x 21 mm. The smallest egg measured was a very tiny egg 16 x 13 mm., laid on June 19, 1934, together with four of normal size.

Incubation Period

The true incubation period embraces

Box turtles emerging from the ruptured eggs.

the time elapsing between the laying of the egg and the rupturing of the shell and the emergence of the turtle. The young turtle may not at once emerge from the soil, but in the writer's experience they make every effort to reach the surface as soon as possible, and probably not more than two or three days at most are spent below the surface of the soil. This delay of one to three days is of no great importance, for the period of incubation depends to a great degree upon the factor of temperature, higher temperatures within certain limits accelerating embryonic growth. Experiments made in 1933 have established the fact that the normal incubation period as observed in the field can be greatly shortened under laboratory conditions.

Six eggs were removed from the soil shortly after being laid. To obviate the chance of choosing an infertile lot of eggs, one egg was selected from each of five different layings. These were placed on a sheet of clean paper resting upon moist soil in a glass dish, over which a larger glass dish of similar shape was inverted as a cover. The eggs were screened from direct light by a piece of white cotton cloth covering them. The dish was kept upon the writer's desk in

the office, where very high room temperatures were experienced throughout the summer. The eggs were examined almost daily, allowing an exchange of fresh air with that enclosed in the dish. Three of the six eggs hatched under these artificial conditions as follows:

Laid	June	10	hatched	July 30—	after 50	days.
"	"	10	"	Aug. 4—	" 55	"
"	"	11	"	Aug. 1—	" 51	"
"	"	17	No embryonic development.			
"	"	18	"	"	"	
"	July	1	"	"	"	

Unfortunately, practically all the eggs of these lots remaining in the soil were destroyed by ants or excessive wetness. However, two eggs of the lot of June 10, one of which hatched in the laboratory on August 4 after 55 days, hatched in the soil, one on September 8 or 9; another on September 10, after 90–91 days and 92 days, respectively. In this test the higher temperatures of the laboratory had reduced the out-of-doors incubation period in the soil about 42 days.

The young turtles hatched under laboratory conditions were quite as plump and vigorous as their brothers or sisters hatched under soil conditions after a longer incubation period.

In the writer's enclosure, hatching in the soil has never taken place until the first week of September, and all viable, fertile eggs had hatched with a single exception before October. The following periods of incubation have been determined.

EGGS LAID	HATCHED			
June 17, 1932	Sept. 10–11	after	85–86	days.
" 27, 1932	" 18–20	"	79–83	"
July 5, 1932	" 25–28	"	82–85	"
" 13, 1932	" 20	"	69	"
June 8, 1933	" 2–4	"	86–88	"
" 10, 1933	" 8–10	"	90–92	"
" 10, 1933	" 9–10	"	91–92	"
" 18, 1933	" 7	"	81	"
" 7, 1933	Oct. 20–21	"	104–105	"

In the colder portions of the country, this turtle becomes much less abundant. It is not a common species in New England, and appears to be very rare north of Massachusetts. The fact that a long incubation period is required for the hatching of the eggs even in the Washington region would suggest that the limiting factor in colder regions may have to do largely with the successful hatching of the eggs. In the colder portions of New England lower soil temperatures would naturally extend the incubation period. The factor of progressively advanced winter conditions, coupled with gradually extended incubation periods, would operate as efficient limitations, in a successful far northward extension of the range.

Behavior of the Young

Although the baby turtles are equipped with a tiny egg tooth, it is doubtful if this plays any very great part in rupturing the eggs. At the time the eggs are ready to hatch, the shells appear thin and soft, and subject to easy rupturing. Oftentimes the fore legs are thrust through the shell before the head emerges, and usually the active exertions of the tiny, restless turtle develop a longitudinal rent, allowing it to emerge. The creature now digs its way to the surface, or in some instances remains for a day or two below the soil, with only its head projecting above the surface. In firm clay soil, the egg cavity may not be entirely filled in the covering process, so that the eggs sometimes repose in a very loosely filled cavity.

All evidence at hand would indicate that the newly emerged turtles go into hibernation for their first winter usually without eating. As soon as they have been liberated in their enclosure they repair at once to the ground-cover of leaves and litter and remain concealed. Every effort to tempt them with tiny earthworms or grubs has given no response.

If the tiny turtles are fat and vigorous when hatched, they are likely to overwinter successfully; sickly individ-

uals usually die. Of 19–20 newly hatched turtles going into hibernation in 1932, five or six failed to over-winter. The majority, however, were in good vigor during the spring of 1933.

During the second season, the behavior of the yearlings shows a decided change. They develop wandering propensities, like the adults, feeding greedily upon all manner of food placed in the enclosure, including small earthworms, grubs, meat scraps, tomato and cantaloupe. Like the adults they are particularly fond of the latter. In late October these yearlings for the most part were able to enter their second winter fat and healthy so far as conditions could be determined.

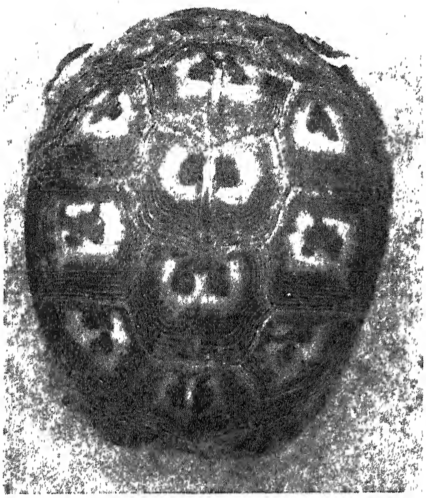
Hibernation and Aestivation

Since the turtles are confined within an enclosure and must accept conditions as they find them, good or bad, every effort has been made to afford them suitable conditions for successful hibernation. It has been found that they are especially inclined to hibernate in low heaps of loose ground-debris, and for this reason all manner of loose weed material and fallen leaves are thrown into the enclosure, covering much of the area with an ample ground cover.

As soon as the cool nights of October are at hand the box turtles show an inclination to become sluggish, and when the cold weather of November appears, the enclosure seems suddenly deserted, so completely have they disappeared. A few individuals may remain active and venture out during warm spells even in December. At this late season, however, they evince no interest in food. A few, showing a very weak hibernating impulse, have been inclined to protect themselves with very little covering. It has been necessary deliberately to place such individuals beneath a suitable covering to avoid their freezing in severe weather. Once freezing wintry weather is at hand, the turtles are seen no more. However, they do not appear to be strictly quiescent, even in their winter beds, for an examination has revealed changes in position, and in some instances sufficient movement to enlarge a cavity around their bodies. In the normal hibernation, the turtle merely digs under the soil or ground debris three to seven or eight inches. In February or March, when warm spells are experienced a few turtles may venture forth, but the majority await the warm weather of April. Of thirty to forty turtles overwintering in 1932–33, three only died, one leaving its hibernation-bed prematurely in February having frozen to death. In every instance turtles that have died have been turtles sick or abnormal in their reactions and behavior.

During the spring of 1933, the warm weather of early April brought a number of the turtles from their hibernation beds. The majority had gone into hibernation in a big heap of loose soil and leaf debris. Even before all had actually left their beds, their heads could be seen thrust through the litter. The hibernation of the first season turtles and young turtles a few years old is similar to that of the older turtles. The tiny babies have usually secreted themselves in well-protected hollows beneath clods and a good covering of fallen leaves and weeds. Immediately after awakening from hibernation, the turtles seem little inclined to eat, and the long winter fast does not give way to a strong hunger impulse until warm spring weather has arrived.

Some observers have spoken of a characteristic aestivation behavior, but the writer's turtles, about 75 in number, have shown no definite midsummer period of inactivity or withdrawal from the heat. In May, the ground debris of the enclosure was raked together and piled in an enormous heap between six and seven feet high, and about the diameter of a large hay cock. The turtles at once began tunnelling deep into this from



THE COLOR PATTERN OF BOX TURTLES SHOWS WIDE VARIATIONS. THIS INIDIVIDUAL
SHOWS WIDE VARIATIONS. THIS INDIVIDUAL
ORANGE YELLOW ON THE CARAPACE.

all sides and even managed to climb to the very top. This heap of cool, damp, decaying vegetable debris and humus was constantly resorted to throughout the summer, where many slept in its tunnels at night or repaired to them to rest and sleep during the heat of the day. No feature of their environment in the enclosure has seemed to satisfy them quite as much as this heap of debris. At no time, from spring until October, have the turtles shown any decided inclination to refuse food, although the hunger impulse naturally seems strongest in early summer. It may be stated, however, that pronounced changes in the liking for certain foods has been noted as the season wore on.

Intelligence, Reactions and Other Behaviors of the Box Turtle

Although the turtle in our classification ranks as a lowly reptile, in the scale of vertebrate development, it evinces a rather remarkable adaptiveness and associative memory in some respects. It is not long until the idea of food becomes associated with one's presence or with particular activities. Daily visits with food soon led them to associate the event of the personal presence with some sort of food, and a general awakening into activity of a crowd of turtles was observable. Frequent digging into their enclosure for earthworms led a number to associate this work with angle worms, and some learned to follow the turning up of the soil fearlessly almost under foot to snatch up the worms. Two large umbrella catalpa trees (*Catalpa bungei*) grew in their enclosure, each season becoming infested with enormous numbers of caterpillars of the Catalpa sphinx.

When it was found that these were eaten with avidity, the trees were often shaken or the caterpillars were beaten down to the ground. The turtles soon associated this event with the idea of acceptable food and they at once repaired to the ground beneath the trees. As many as 15 to 20 sometimes appeared to catch the crawling caterpillars. All caterpillars are not as acceptable to the turtles as the Catalpa sphinx. On one occasion the beautiful celery caterpillar was placed before them; it was intently examined by a number, but all refused to touch it. There was probably some nice sense of discrimination involved which would explain their behavior.

Our box turtles soon became fairly tame, and a number could be induced to eat pieces of bread or other food from one's hand. As soon as they became aware of one's appearance within the enclosure, they could be seen emerging from their burrows in the heap of debris to peer about.

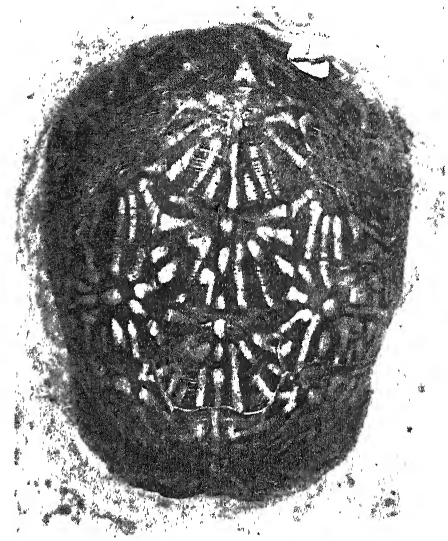
Early in the season they were voraciously fond of earthworms, which were dug up and offered to them at every opportunity. The slightest movement of a grub or worm in the soil is detected by their watchful eyes, but they are quick to detect and to recognize other food which is lifeless or does not move. The big chrysalides of the Catalpa sphinx

were readily recognized and eaten. To seize a huge earthworm or grub, the turtle follows the creature to its head, all intent with outstretched and strongly arched neck. There is a sudden snap of the jaws upon the worm, and a quick clawing at the creature with one fore foot or the other, to tear its body apart. This is the behavior of the babies as well as the adults. Such material as cantaloupe, tomatoes, cooked potatoes, bread or other bulky food is eaten by cutting out big bites with its powerful sharp-edged bony jaws and swallowing them without chewing.

Although all manner of food is eaten, the creatures appear to prefer variety in their diet; angle worms, which were greedily eaten early in the summer, were steadfastly refused later in the season. Likewise tomatoes, which at first were very inviting morsels, ultimately were almost ignored and a preference shown for blackberries and cantaloupe. Pears, plums and other fruits also had their season. So it would seem that the most suitable diet for captive box turtles should include a good variety of foods.

Shade and clean water for bathing and drinking purposes should be afforded them in an enclosure. The box turtle is very much of a terrestrial creature, but they are very fond of immersing their bodies in water, many of them remaining in their shallow pools for long periods, both day and night, now and then elevating their heads for air. Deep pools from which they can not readily escape are dangerous to the box turtle, for they can not tolerate long immersions, like water turtles, and several have come near drowning in our tests.

Although the digging of the egg-cavity is invariably performed by the hind feet, the fore feet are always used to dig the hibernation bed, and to tunnel into piles of leaf and humus debris. In the digging of the egg-bed the hind feet are also invariably used in alternation.



DISTINCTIVELY MARKED BOX TURTLE
SHOWING A WIDE DIVERGENCE FROM THE TYPE OF MARKING SHOWING IN PRECEDING FIGURE.

What, then, would a female turtle do with one hind foot? This question was answered by a female found with one hind foot amputated and long since healed. The creature dug her hole as every turtle with two feet does, strictly alternating the digging movements. However, the amputated foot could perform no actual digging and the flask-shaped cavity was unsymmetrical, the cutting being done entirely by the claws of the normal foot. In spite of this handicap the eggs were laid and covered successfully. It is probable that the turtle was even quite unaware of her deformity, since pseudesthesia would exist in the nerve endings of the severed limb.

The box turtle is usually a harmless, inoffensive creature, and can rarely be induced to snap or bite. However, several cases of vicious snapping have come to the writer's attention. On one occasion, while carrying one of these creatures near his body in a walk through the woods, it snapped its jaws upon the strap of a vasculum slung over his

shoulder and held on viciously for some minutes.

Box turtles sleep much through the day, especially during the heat of midsummer. At such times they may sleep very soundly in their tunnels in the piles of leaf and humus debris. The writer has sometimes carefully lifted them up without awakening them, so soundly have they slept; on awakening and finding themselves in the hand they appeared quite surprised and disturbed, making violent efforts to escape.

The night time is a period of inactivity and sleep for all except the females during the period of egg-laying. The coming of evening then stimulates an entirely different reaction, for they settle down to the serious work of excavating their egg-beds, laying and covering the eggs, a procedure which may persist far into the night, while their fellows sleep. This abrupt change of response to darkness is a peculiar one, for, if they are approached carefully while at work, the presence of a powerful flashlight directed upon them or the repeated blinding flash of a photographic flashlight will not seriously disturb them.

It has been shown that the females almost invariably begin the work of excavation of the egg-bed in late evening or near sunset, so that the eggs are generally laid in the darkness of night. It is evident that the turtle responds to some positive factor attending the close of the day. Is this response related to cooler temperatures, to diminishing light intensities or to an awareness of the lowered position of the sun in the western sky? The temperature factor, it seems to the writer, is too variable to establish a definite evening relationship throughout the entire egg-laying period. The writer is inclined to believe that some phase of the light factor or the position of the sun regulates this nice behavior of the females, and it would be very interesting to bring about gradually an artificial darkness for several days during the egg-laying season to determine the responses of the females. Under the particular conditions of the writer's enclosure, the females headed northward or toward points between west and north 17 times out of 25 instances observed during 1932 and 1933, or 68 per cent. In 8 instances during this period the females headed in easterly directions or toward points west and south, or 32 per cent. This seems to be a frequency more than accidental, but it may have been related to some local factor of the environment within the writer's enclosure.

The box turtles usually live peacefully together in their enclosure, but they can become very vicious fighters. In one instance two turtles eating from the same dish suddenly became enraged. Both quickly adopted a characteristic fighting attitude as they faced each other. Each lifted a front foot from the ground, and held himself as high as possible in a rearing position on the remaining three legs. At the same time they engaged in a peculiar teetering motion. With the quickness of lightning, one suddenly struck savagely at the other's head, its powerful jaws catching its adversary's beak. The turtle attacked retracted its head instantly into its shell, breaking the hold with a loud snap. The big aggressive fellow now stood high upon three legs over its enemy, one front foot uplifted, its reptile-like neck outstretched, waiting motionless with savage ferocity in its expression for it to protrude its head again. This turtle seemed well aware of danger, and merely waited until its vicious enemy tired of the fray and repaired to the food again.

Disease, Enemies, Etc.

The general health of turtles appears to be largely a matter of proper feeding. Many turtles in the field probably want for food much of the time, and some have been found thin and light, indicating a

half-starved existence. Such individuals have gained in general health, weight and vigor with better feeding.

The general health of the turtles carried over from 1932, around 60 in number, was far better during the seasons of 1933 and 1934 because they were afforded a more generous and varied diet.

Turtles are sometimes picked up in the field with one eye destroyed; some have been found with a foot missing. The development of peculiar swellings localized upon the face and neck, sometimes on one, sometimes on both sides, is a rather common affliction. The swelling sometimes greatly enlarges and closes the eye, or makes the retraction of the head into the shell difficult or impossible. This trouble may affect the most vigorous turtles and it usually appears shortly after the hibernation awakening. This swelling appears to be purely superficial, involving the fleshy parts of the face and neck, but the affected turtles became profoundly ill and lethargic out of all proportion to the seemingly slight, local nature of the swelling. As soon as any swelling of the face is evident, the turtle's behavior changes. It becomes lethargic, spends much of its time in the water, both night and day, sometimes remaining in the water for days. As the swelling enlarges, the eyes are closed, the head becomes misshapen and the appetite fails. Although this condition may persist for weeks, a gradual subsidence of the swelling usually follows, or in many instances a transition of the generalized enlargement into a more restricted and localized elongated outgrowth which projects from the face. Invariably this particular form is scratched off, and has been left upon the soil as a big, fleshy elongated hump. The clean, superficial scar remaining soon heals, and at once the normal behavior of the turtle is resumed. Although this trouble has been rather frequently observed, no turtle has died as a result, and usually by autumn none show such swellings. Some have seemed such hopeless cases, with the eyes tightly closed, as a result of these swellings around the face that it was feared recovery would be impossible. In due time, however, such individuals recovered and attained perfect health. It is rather puzzling why such afflicted individuals repair so consistently to water, as if they were in a state of fever. Fever, however, in a cold-blooded creature approximating more or less the temperature of the environment can not be of the same order as our own. Yet it is possible that a feverish condition somewhat above that of the environment obtains, even though the normal body temperature of the turtle may vary widely, depending upon environment.

These swellings do not seem to be of the nature of simple abscesses, and they do not rupture into open sores. There is some reason to believe that parasitism of some kind may account for their presence.

A condition resembling cold and perhaps pneumonia not frequently affects turtles, the nasal passages discharging and sometimes with foam about the mouth. Affected turtles become lethargic and disinclined to eat; recovery usually ensues.

In several instances a peculiar cloacal elongation and eversion has affected some turtles. The cloaca becomes so protruded that the posterior lobe of the plastron squeezes upon it. This is a very serious ailment, for the everted cloaca becomes infected and infested with flesh-eating larvae, and the turtle dies. The cause of this trouble is obscure. Postmortem examination has revealed a strictly local condition as far as could be seen, associated with the cloaca alone.

Box turtles, like all other invertebrates, are infected with internal parasites. Some have been found with heavy ascarid infestation, these crawling in

numbers from the cloaca. However, a light infestation appears to cause no serious symptoms; although they may represent a normal association with the turtles, the latter are undoubtedly better off without than with them. It is known that the troublesome "chigger" occurs on the box turtle, but probably it is not more worried than human beings by this pest. The eggs at every stage of development, before hatching, are often cleaned out by tiny ants, one being the species *Solenopsis molesta* Say,[1] and the writer is inclined to believe this is the species causing the usual destruction. The eggs are also destroyed by crows and by some dogs, which can locate them by smell. The great scourge in the box turtle's life is fire sweeping over its domains, and the automobile with drivers who deliberately or carelessly crush them on the highways. The death rate on the highways in spring during the restless mating season is very high, and can not but greatly decimate their ranks if persisted in year after year. Some well-known scientists have told me that they always kill them because they eat their tomatoes, but it is a deplorable attitude toward life and nature to give the poor reptiles, harmless and even positively beneficial, no chance to dwell among us. Some scientists have told the writer that the extermination of life, whether it be plant or animal, means nothing if it is done in the progress of the civilization of man. In its higher aspects, however, the true progress of man is not a relationship alone with mechanical appliances and with the materialism of the universe turned into money values. The higher progress has to do with spiritual values dependent upon elements of truth, art and religion gained from the universe. Genuine progress is not one of untrammeled and careless destruction of the original environment which man has found, but one of thoughtful preservation so far as possible of all those things of interest and of utility which occur around us. In this mood the poor box turtle has a just claim on our sympathies and deserves our consideration and protection.

[1] Identified by Dr. Wm. M. Mann, of Washington, D. C.

"MICROMEN" OF THE SOIL

By Dr. IVAN V. SHUNK

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When a man undertakes to grow a crop of corn, cotton, tobacco or what-not, he either knowingly or more probably unknowingly requires the services of many, many laborers. He may hire some one to plough and harrow the ground or he may do that himself. Later he plants the seed and from time to time cultivates the crop.

Let us suppose that the ploughing turns under some plant remains, cotton stalks, corn stubble, grass or weeds. The farmer tells his neighbor that this organic material will enrich the soil and aid in his next crop. He may add also some stable manure or may plough under a cover crop.

While the farmer is thus preparing and planting his soil, he is, for the most part unwittingly, letting a series of contracts. It is true that these contracts are not drawn up according to the latest legal procedure, but they are binding nevertheless. In fact they are as binding as the famous laws of the Medes and Persians.

We refer to the contracts let with the large number of different subdivisions of that great fraternity, "The Amalgamated and Confederated Order of 'Micromen' of the Soil." This great fraternity comprises all the bacterial workers who carry on chemico-biological changes in the soil. In this paper we shall mention only the bacterial fraternities and not attempt to include other important groups, as the fungi, actinomyces, protozoa, algae and other lowly denizens of the soil.

Let us refer to a number of the principal labor unions that make up this great fraternity of micromen.

First, there are the day laborers that do the rather ordinary work of tearing apart the molecules of plant and animal remains. These might be referred to as wrecking crews, and while many bacteria can break down numbers of different substances, there are certain local labor units whose contracts call for only certain types of labor.

Then there are the highly skilled or specialized workers which carry on the more specialized phases of the soil work.

Let us look first at the laborer class of wrecking crews. Here we have the bacteria of general decay, many of which are rod-shaped spore formers. Many are rod-shaped non-sporing bacteria, and there are also spherical bacteria. The main reason why these bacteria of general decay carry on is because these micromen get their food in this way. They can not eat unless they work, and in part at least their work consists of eating. A microman for instance, of the shape but not nearly the size of a hot dog, turns loose out of his body certain enzymes which digest or make soluble organic substances which the microman then absorbs and utilizes in building his body. We have been frequently told in these days of increasing social complexity that "No man liveth unto himself," a well-known biblical statement. Here let us notice that rarely does a microman live unto himself. He ordinarily absorbs soluble food that was digested by enzymes excreted by his ancestors that lived ten or more generations in the past, perhaps two to ten hours before. These micromen may come into existence, work faithfully, grow and reproduce within the short space of thirty minutes.

Even the micromen of the lower orders in the labor unions require very definite working conditions; in other words, they work under a code not unlike that of the

NRA. If the soil is too cold they lie in bed and will not work. If the air is too poor they demand improved ventilation before they will work. If the number of hydrogen-ions is excessive in their locality, they likewise refuse to budge. No amount of cajoling on the part of the farmer is here of avail; he simply must live up to his part of the contract, namely, that working conditions shall reach a minimum set of requirements before any work is done.

We have spoken of proper ventilation. That is all very well for some of the unions. Others care little about ventilation and work either with or without an available supply of oxygen, while, strangely perhaps, there are numbers of local unions who just despise a well-ventilated soil. Their desires are not satisfied until all free oxygen is removed, and in fact some seem to be actually injured by free oxygen.

In this connection let us see how different unions are willing and ready to cooperate. One that demands air, an aerobic group, consumes the oxygen available, and thus helps his brother craftsmen, the anaerobes, to live and labor.

Many human laborers are insistent in their demands that their food contain certain meats, vegetables, fruits or desserts. For instance, cases have been known where human workers have refused to continue their labors until food agreeable to their tastes was furnished. We have a closely similar situation with the micromen. If considerable straw is present in the soil, the farmer hopes to see it decomposed and expects the bacteria and other soil organisms to carry out its decomposition.

A number of guilds of these tiny craftsmen are able to attack cellulose. Some aerobic rods, certain anaerobic species and at least one Spirochaete work readily and in the case of the latter organism solely on cellulose. However, these organisms will do this job only provided their working conditions are met. They simply demand a source of nitrogen in their food. It is true they may not be insistent on T-bone steaks, as their human counterparts, but have nitrogenous substances they will or they promptly go on strike.

A friend was in the habit of feeding some micromen a diet of shredded filter paper and certain mineral salts, including nitrogenous salts. These little workers rapidly destroyed the filter paper added to the pots in which the soil was kept and became exceedingly numerous. However, when an additional amount of filter paper was added, if the nitrogen supply was forgotten, the little fellows promptly quit working. How could you expect them to work when they could not build their bodies out of the food that was furnished, since to make protoplasm, nitrogen was necessary as well as the elements carbon, hydrogen and oxygen present in the filter paper.

Interestingly enough, the cellulose, in this case filter paper, even if additional nitrogen was not added would slowly but very slowly disappear. You suppose that some of these cellulose attacking microworkers decided to break their contracts? Decidedly not, but as some of their brethren died, they were able to digest the dead bodies of their brother workers with the help of other bacteria of decay, and thus carry on slowly. Let us not consider these micromen cannibals, for they do not kill their brothers for food, but if some of the craft have died from other causes, then the case is different.

Let us now consider briefly the activities of some of the highly skilled or more special guilds of this great fraternity in the soil. We do not expect carpenters to begin the superstructure on a house until the masons have completed the foundation. Neither must we expect a group of workers like the nitrifying bacteria to begin their work until their friends, the bacteria of decay, have brought their work to completion and

changed the nitrogen originally present in organic combination to ammonia.

We have two separate unions of the nitrifying bacteria. One group must have ammonium salts which they oxidize to nitrites and in this way obtain the energy needed to build their bodies from carbon dioxide and mineral salts. They will consume no organic food whatever. Just as soon as these nitrite formers have changed the ammonia to nitrites, the nitrate formers jump in on the job and convert the nitrites to nitrates.

Now the farmer is getting results, for the ammonium salts in the soil and the nitrates are taken up by his crop plants, and these crops grow. What has the farmer done, and just how has he let the contract to the micromen? He has stirred the soil and increased the ventilation, giving his bacteria the oxygen so many of them demand; he has furnished food and minerals which all of them need. If the soil had too many free hydrogen-ions he may have tied up a lot of them so they could do no more mischief, by the addition of lime. All in all, while the farmer probably does not know it, he is satisfying the demands of the labor unions to which these microworkers belong.

Another of the special guilds of microworkers has specialized in a different direction. This group has learned of a better way to get along than any of its fellows. The free-living nitrogen fixers, called by their human admirers Azotobacter and Clostridium, do not have to depend on the organic or inorganic material of the soil for their nitrogen. If protein or peptone is handy, they will eat it of course, but they do not require it. In fact this special group of micromen show evidence of advanced ability, ability not possessed by not only their fellow craftsmen of the soil, but not possessed by the higher plants or animals, even man.

Although the air we breathe is about four-fifths nitrogen we can not use this nitrogen, neither can the green plants. In the nitrogen-fixing bacteria we have a few groups of micromen who know how to get their nitrogen from this inexhaustible source. We might suppose that these microworkers, having learned how to get their nitrogen from the air, would be able to grow without organic food, but not so. They are still dependent on sugars or substances closely akin to sugars for their energy requirements and disdain to touch celluloses and lignins.

Azotobacter happens to be an aerobe, while Clostridium is an anaerobe. Hence it happens that not infrequently these two groups are found growing in partnership, the Azotobacter developing until the oxygen is used up, and then the process of nitrogen fixation being continued by the anaerobe, Clostridium.

The Azotobacter cells usually quit when the hydrogen-ion concentration reaches an acidity referred to as pH 6.0 and refuse to grow under more acid conditions. Just at present experimental work is under way to try to learn just what grievance the micromen have. Are they disturbed by the hydrogen-ions present or do they object for some other reason, since we know that occasionally they do work under more acid conditions?

It may be that the farmer decides to plant a leguminous crop to help enrich his soil. This attempt will avail him nothing unless certain humble nitrogen-fixing bacteria are present and working in his soil. To be sure he has the right ones available he may import labor to his liking, by inoculating his seed.

The nitrogen-fixers that live on legume roots in the soil, like their other associates of the soil, belong to a number, perhaps a dozen or more of different unions. One will grow only on soybeans,

for instance, another will attack vetches and garden peas, another will grow on alfalfa and sweet clover and so on.

These nitrogen-fixers attack the roots of the leguminous plant and the plant responds by growing a nodule in which the micromen live and labor. We may consider these bacteria as parasitic on the roots because they demand and get organic food from the legume plant. However, the legume is able to fight back and take from the micromen a good deal of combined nitrogen, so the parasitized legume plant is really the gainer after all.

Another highly specialized group of microworkers include the so-called sulfur bacteria. Some of these oxidize hydrogen sulfide formed by the bacteria of decay to sulfur and some change sulfur to sulfuric acid. In a few cases the farmer has been instructed to import sulfur bacteria, but this is largely unnecessary as enough of them are usually already there waiting for a chance to do their share. Now what do you suppose becomes of the sulfuric acid? Of course, if any happens to come in contact with a piece of filter paper or a similar piece of organic substance, it may have the same effect as when sulfuric acid is accidentally spilled on your suit. You know it just simply ruins good clothes to have sulfuric acid drop on them; they never look the same afterwards. In the soil there are bases available, and as soon as the sulfuric acid is formed, it unites with them, forming sulfates which may be taken up by the plants.

Without these micromen of the soil, together with the fungi, Actinomyces, etc., which we have not space to include in this paper, dead matter in the soil would never decay, elements would remain tied up for many years, and the world would be in a bad way indeed. For this reason we are in absolute need of the valuable services rendered by these largely unseen and unsung heroes of the soil.

Let us not conclude this paper without a brief mention of the gangsters or racketeers among the micromen, for here we have another counterpart of a phase of modern anti-social activities among these lowly microbes. In all soil there are lurking sinister forces which may cause considerable damage if certain gangs of the racketeering micromen can just get a chance to work. We refer to a group of bacteria known as denitrifiers. They attack the nitrates of the soil and destroy them, giving off nitrogen in the form of a gas and it is then lost from the soil.

Another thing about these marauders is that they sometimes cooperate with other ordinarily respectable micromen in carrying out their mischief. For instance, *Bacillus coli* may break down nitrates to nitrites and along comes *B. denitrificans* and turns the nitrites into free nitrogen and then it is lost.

How can the farmer protect himself against this band of outlaws? He can see to it that the conditions in the soil are such that these destroyers can not work. Good aeration is one of the easiest ways of preventing their action and this may be obtained by cultivation and drainage.

HOW FAR CAN I SEE?

By W. E. KNOWLES MIDDLETON

METEOROLOGIST, METEOROLOGICAL SERVICE OF CANADA

The question which forms the title of this paper is one of the most important of all the questions which the aviator puts to the meteorologist. Upon the correctness of the answer hangs the safety of the pilot and of his passengers, and the delivery of valuable cargoes of mail and perishable goods.

The present-day meteorologist is able to give answers of remarkable precision to many of the questions asked by the public. His occasional failures, once a favorite theme of the comic press, are now realized to be due to insufficient data rather than to guessing. The accuracy and range of his predictions are being extended rapidly by the use of new knowledge about the atmosphere we live in. It is the more surprising that the "seeing," the clearness or obscurity of the lower air, continues to be measured, or rather estimated, in an entirely primitive manner. We shall find later that there are reasons for this apparent lack of progress.

In weather jargon, the distance we can see on any given occasion is called the "visibility." Not, be it noted, the clearness of the seeing, but the distance. Purists may smile if they like, or they may feel as Professor Brander Matthews did when he discovered (not in a Service Club paper, but in an electrical journal) the "separately excited booster." Others, more accustomed to the strange verbal progeny of applied science, have only to remember that when we speak of *the* visibility we refer to the *range of vision,* no matter what the dictionary may say.

The readers of The Scientific Monthly will be well aware that the atmosphere is composed largely of nitrogen and oxygen, with smaller but easily measurable amounts of carbon dioxide, argon and other gases. These gases are remarkably transparent; it may be calculated that in an atmosphere containing nothing else, an aviator could make out a mountain at least 250 miles away. The fact that such great visibilities seldom occur suggests immediately that the air must be "full of a number of things" not mentioned in our list of gases.

Always, of course, there is water-vapor. Now water-vapor is also very transparent to the kind of radiant energy which our eyes recognize as light, as long as it has no opportunity to condense into little drops.

Rather larger than the air-molecules are the so-called "nuclei," which seem to consist sometimes of groups of gas molecules, sometimes of tiny particles of salt from the sea spray, and sometimes —especially near cities—of products of combustion. When there are many of these, with a little water collected on each one, the air is hazy.

Now these haze-particles form excellent pegs, so to speak, on which to hang water-vapor molecules. Most of them are hygroscopic, which good Greek scholars will take to mean that they watch out for water molecules and, having found one, will not let it go. When one of these haze particles has accumulated enough water to make it about 1/5,000 of an inch in diameter, it begins to act differently towards light, and we call it a fog droplet. For this diameter is rather larger than a wave of visible light, whereas the haze particle is about as big as a wave or somewhat smaller.

The effect of particles of different sizes on light waves is a subject which bristles with mathematics. An analogy

which has often been used points to the rows of piles which support a pier over the ocean. Suppose these piles are two feet in diameter; then the little ripples, a few inches long, on a calm day, will be reflected from their broad surfaces; but the big combers will wash right through, though their height may be diminished. This is rather obvious. But if you watch very carefully, you will see secondary waves being sent out from the piles in all directions. In a similar way, the particle which is large in respect to the waves will treat the various colors (wave-lengths) alike. This is why a fog looks white. But the tiny haze particle scatters the short waves of blue light more than the longer waves of red light, and the result is that a haze looks blue when you look *at* it, but makes a light—such as the setting sun—appear reddish when seen *through* it.

The reader will naturally object, "But when I see a distant mountain through hazy air, it looks blue." This objection brings us to a very important point, which is vital to our subject.

When we see a distant lamp at night, we see it by virtue of the light which gets through the intervening mass of air-molecules, haze-particles or fog-droplets to the pupil of the eye. If there are too many of them, we can not see the light. But when we see the "blue of the distant hills," we deceive ourselves; what we really see is the blue of the air between the hills and our eyes. As our gaze travels from hill to hill into the distance, a point is reached where we can not quite be sure—is it a hill, or the sky beyond? The air-light at this point has come to be nearly (about 98 per cent.) as bright as the horizon-sky, which latter is, of course, all the air-light between us and empty space.

The difference between the two cases can perhaps be expressed by saying that the distant light at night vanishes because of the light which the air takes away; the distant hill in the daytime, because of the light which the air places in the way. I believe that this simple way of putting it has a true scientific standing, in that it leaves out nothing essential.

Now if it is haze we are looking at, more of the blue light than of the red is scattered into our eyes, making the distant hills appear blue; while if we are looking through a great thickness of it at a distant lamp, the blue is scattered in all directions more than the red, so that the light which does get through is reddish.

With this in mind we can define the daytime visibility as the distance at which an object becomes so nearly as bright as its background that we can no longer see its outline. It was suggested above that this takes place when one is about 98 per cent. as bright as the other. Put in another way, the *contrast* between object and background is then about 2 per cent. It is one of the properties of the human eye that it can not distinguish a contrast less than this. If we could devise an artificial eye which should be super-sensitive to small brightness differences, and train it on the horizon, it would be able to see distant objects farther and farther, till the curve of the earth got in the way.[1]

It is not immediately obvious that this is so. It would be natural to think that if, on a certain day, a wooded hill 23 miles away were 90 per cent. as bright as the horizon, and a similar hill 30 miles away 95 per cent. as bright (a case which might occur), then a hill 37 miles away would be 100 per cent. as bright. But that is not what happens. Actually the 37-mile hill would be $97\frac{1}{2}$ per cent. as bright as the horizon, and therefore just within the range of vision; a hill at 46 miles, 99 per cent.; at 69 miles, $99\frac{9}{10}$ per cent. And 100 per cent.? Never; at least as long as the hill remains a real

[1] This is true in clean air or in haze. It is probably not true in fog (certainly not in dense fog) for reasons which can not be discussed here.

terrestrial elevation, standing on the ground, with air behind it again. The series of percentages which I have written down is much like the series of numbers we obtain if we add $\frac{1}{4}$ to $\frac{1}{2}$ and $\frac{1}{8}$ to the sum and $\frac{1}{16}$ to the new sum and so on—always getting closer to 1 but never reaching it. It is rather like pumping the air out of a globe, and removing, say, $\frac{9}{10}$ of the air still in the globe every minute. After hours of this, there will still be a little air left.

The fact that I was able to write down the above percentages is evidence that we know the law connecting the apparent brightness of an object and its distance. The law is a very simple one, and rather like the law which connects the weight of a healthy child with its age; but it was not explicitly stated and proved till 1924.

The obscuring power of the atmosphere at any given time and place is expressed by a number known as the extinction coefficient. When a little algebra is done with the law referred to above, it is found that the extinction coefficient is equal to a constant divided by the visibility of a dark object against the horizon sky. The importance of this is that it demonstrates that the visibility of such an object really is a measure of the obscuring power of the atmosphere, or at least an approximate one.

The law regarding the visibility of lights at night is not quite so simple, for it involves the candle-power of the light. However, if this is determined, any given value of the extinction coefficient corresponds to some unique distance of visibility.

The actual measurement, or rather estimation, of the visibility is a very simple process. The observer looks at a previously chosen set of objects at various standard distances, beginning with the nearest, and notes which one is just visible. "Just visible" is generally agreed to mean that the shape of the object can be distinguished—not merely that something is there. The visibility is then the distance of this last visible object.[2] At night, lights at various distances are observed, and the distance of the farthest one which can be seen is recorded.

This procedure can be highly satisfactory provided: (1) that the observer has normal eyesight; (2) that a sufficient number of objects and lights are available at suitable distances; (3) that the objects are fairly dark in color and are seen against the sky; (4) that they appear approximately equal in size; (5) that the lights are of the proper candle power (the more distant ones should be much brighter); and (6) that there are no important sources of artificial obscurity, such as factory towns, between the observer and any of the marks.

The reader will note that we have here a series of "ifs" almost sufficient to afford material for a parody on Mr. Kipling. It is fairly certain that there is no meteorological station on earth at which all these conditions can be satisfied. Consequently, meteorologists have looked about for an instrument which will enable them to measure the visibility even if only a very small number of objects and lights is forthcoming.

There is no such instrument at present which is entirely satisfactory for meteorological use. All but one—as far as I am aware—are limited either to day or night use; the one exception is prohibitive in cost. Several of them require observers trained in optical measurements—a fatal defect in routine work. One or two instruments which seem promising in a restricted way have failed, somehow, to be generally adopted.

The best we can do at present is to choose our objects carefully, having them as dark as possible, always against the sky, and of dimensions proportionate

[2] This is the American practice. In Europe and elsewhere the convention is that the visibility is the distance of the first standard object which can not be seen. We can only assume that there must be a hidden reason for this.

to their distance; and to choose our lights with due regard to their candle-power. Very great improvement in these respects could be made in current practice, and no doubt will be made as the underlying principles become more widely known.

The visibility is related in a general way to the weather, the time of day and the season of the year. The actual form of the variation is very different in different parts of the world, and there exists a tremendous literature on the subject, chiefly in papers on regional climatology. In the space available we can indicate only a few general principles.

In some places, such as central Europe and parts of eastern North America, the visibility is generally greater in summer than in winter. In others, such as the region of the Grand Banks, the reverse is true. On the great plains of North America, the seasonal variation is not very well marked, though the very greatest visibilities occur in winter, when the cold air, overlying the snow-covered ground, contains very little moisture and almost no dust.

Visibility bad enough to be a danger to aviation is most frequently due to the presence of fog. It is a general rule that in maritime climates fog is most frequent in the summer, in continental climates in the winter. This effect may occasionally be so marked that an air-route which normally lies along a coast may have to be moved a short distance inland during the summer months; or a terminal airport at a coast city may have to be provided with a convenient auxiliary landing field at some distance from the sea.

The visibility is usually greater in the afternoon than in the morning. This is because the heat of the sun, warming the hazy layers of air nearest the ground, causes them to ascend, and the resulting stirring-up of the air in the first mile or so distributes the haze particles through a larger volume. With the coming of night the mixing ceases, and the air again begins to stratify, with most of the haze at the bottom. A strong and persistent wind, however, interrupts this normal nocturnal process, while a heavily overcast sky and calm weather during the day prevents the air being stirred up. At most seasons and in nearly all localities, fog is most frequent during the early morning also, a fact which shows up in statistical summaries of visibility observations.

The reader has no doubt recently become aware that the temperate zones are a sort of battleground, the scene of constant warfare between masses of tropical air from nearer the equator and masses of polar air from higher latitudes. The changing fortunes of these mighty antagonists result in this part of the world being covered alternately by air of the two kinds. Our present interest in this lies in the fact that the polar air is usually very much clearer than the tropical, especially in winter and over the continents, partly because it is very much drier, and partly because of its origin over clean fields of snow and ice. In the central and midwestern states and the central provinces of Canada, it is not uncommon for the visibility to increase from two or three miles to fifty or a hundred miles in the space of an hour or so, as the advancing front of the polar air pushes back the air from the tropics. Even when this atmospheric victory is not accompanied by thunder and rain, the great and sudden increase in the visibility will tell the watchful observer that the battle has been won.

The meteorologist's knowledge of the movements of these air-masses, gained by means of his world-wide "intelligence department" and embodied in the daily weather maps, renders more and more trustworthy his answer to such a specific question as "How far shall I be able to see over western Pennsylvania this afternoon?"

COSMIC RAY BURST PHENOMENA

By GORDON S. BROWN

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FOR almost three decades the mystery of the origin and nature of cosmic rays has presented a puzzle of the first magnitude. During recent years, however, there has been a great deal of activity in the work of unraveling this mystery, and many data relating to it have been collected. It is apparent to those familiar with this field of research that the energy of the radiation as received is too small for it to be of commercial importance of itself. But the processes involved impart far greater specific energies to corpuscles than any others yet known, indicating that if we ever become able to understand and control the mechanisms involved in cosmic-ray phenomena and learn how to reproduce them we may make available a new and potent source of energy.

The only known method of detecting cosmic rays is through the ionization which they produce in gases. In fact, a good present-day definition of a cosmic ray would define it as "a radiation penetrating the earth's atmosphere, which is only detectable in terms of the ionization which it produces in gases." Three types of cosmic-ray measuring apparatus have been evolved which depend on this ionizing property of the rays for their action, namely, the ionization chamber, which measures the rate of production of ions, the Geiger-Müller counter, which uses the ionization to initiate an electrical discharge and counts rays or groups of rays, and the cloud expansion chamber, which makes evident the paths of the rays by the condensation of droplets of liquid on the ions formed by the corpuscles. The devices employed to measure the ionization-currents in the early ionization chambers were relatively insensitive and gave indication only of average values of the rate of ionization over considerable periods of time. As more sensitive types of apparatus were developed it became possible to investigate more in detail the manner of production of the ionization.

Hoffman, working in 1928 with a large and sensitive apparatus, noticed that occasionally there occurred very large momentary increases in the rate of production of ions. These sudden increases he called "Stösse." The English term given to the same phenomenon is "burst." The ionization is produced by ionizing rays crossing the chamber, and because these rays occur in a more or less random manner there will result statistical fluctuations in the rate of ion production. For this reason there was at first some doubt as to the reality of these bursts. However, for a random distribution in time of the rays, there exists a calculable relation between frequency and magnitude of statistical fluctuations and it can easily be shown that the observed frequency of occurrence of bursts of large size is very much greater than would be expected if they were all due to statistical variations. Hence, there seems to be no doubt that the bursts are a manifestation of some real phenomenon, perhaps different from that which produces the usual type of average cosmic-ray ionization. All experimenters working with sensitive ionization-chamber apparatus have since found these bursts. They have also been photographed in Wilson cloud-expansion chambers, and detected with Geiger-Müller counters.

Early in the spring of 1934 the first of a new series of large cosmic-ray intensity meters was completed at the University of Chicago. These instruments were designed and constructed under the

direction of Professor A. H. Compton of that institution and sponsored by the Carnegie Institution of Washington.

The spherical ionization chamber of this instrument has a diameter of fourteen inches and is filled with very pure argon at fifty atmospheres pressure. Argon gives a better yield of ionization than lighter gases because the heavier atoms form better targets for the rays. The yield also goes up very nearly linearly with pressure for pure argon. The current measuring device is a Lindemann electrometer, which is arranged to record photographically the rate of production of ions continuously on a moving film. The instrument is also provided with mechanisms which compensate for pressure and temperature fluctuations, and the chamber is shielded against local radioactive rays by a concentric layer of lead shot of twelve centimeters effective thickness. The writer, with Henry A. Rahmel and Ralph D. Bennett, of the Massachusetts Institute of Technology, took the first meter to be completed to Colorado for a field test at different elevations.[1] The instrument was operated for about two hundred hours at each of three elevations; namely, 5,300, 10,600, and 14,100 feet above sea level. The resulting records, together with another series for about 200 hours observation made for us at Chicago by Drs. R. L. Doan and E. O. Wollan, were examined for "bursts." The magnitude and frequency of the occurrence of these "bursts" or sudden increases in ionization were recorded.

At about the same time, Drs. C. G. and D. D. Montgomery[2] took another apparatus to Pike's Peak and made a similar series of observations. Their apparatus was designed primarily for the study of bursts and was operated at a higher sensitivity for this purpose than was ours. They also studied the effect of measured amounts of lead placed above their ionization chamber.

Any conclusions which might be drawn from these observations concerning burst phenomena depend on the result of a statistical analysis of the data. For a very satisfactory analysis of this sort we feel that a much larger number of data would be necessary. However, the following trends were indicated:

(1) The frequency of bursts of any given number of ions increases with elevation at somewhere near the same rate as the total average rate of production of ions.

(2) The magnitude of the largest burst likely to be observed at any given elevation increases somewhat more rapidly with elevation than the average rate of production of ions. The largest burst in our Chicago records amounted to about 150 million ions, whereas the largest observed at 14,100 feet elevation (the summit of Mt. Evans) exceeded the range of the instrument and amounted to more than a billion ions. The relative rates of ion production at the two places is in the ratio of about 1 to 3.

(3) The bursts included in the study contribute less than one per cent. of the total ionization. However, this study included only bursts of relatively large sizes. The possibility that all the ionization comes from bursts is therefore not excluded because the contribution of the smaller and much more frequent bursts is at present unknown.

(4) The physical dimensions of the ionization chambers have not yet exceeded the physical dimensions of the bursts. As instruments have increased in size the observed number of ions set free in the average burst has also increased.

There remain many interesting fields for speculation as well as for experiment. For instance, the mechanism of the bursts is not yet understood. If the release of the ions in a burst results from

[1] R. D. Bennett, G. S. Brown, H. A. Rahmel, *Phys. Rev.*, 47: 437, 1935.

[2] C. G. Montgomery and D. D. Montgomery, *Phys. Rev.*, 47: 429, 1935.

the simultaneous passage through the chamber of many rays of the kind ordinarily seen in cloud chambers, then our largest burst must have been the result of between five and ten thousand of these rays. Such a large number of rays can not have come from any single atom unless the constituent parts of an atom are much more numerous than has been supposed. Nor is it to be expected on the basis of known facts of interactions between rays and nuclei that several atoms would cooperate to produce such a large number of rays. There is of course the possibility that a reversal of the process of conversion of mass into energy might be taking place. Also there has been some indication recently of the occasional occurrence in Wilson cloud chambers of particles which produce very large numbers of ions in a small region. A particle of this type might account for the very great numbers of ions released.

The energy released in our largest burst totals up to a surprisingly large value. Allowing 30 electron volts per ion pair we get some 3×10^{10} electron volts of energy manifest within the chamber. The absorbing power of the argon is something less than one fiftieth part of that of the shield, so that if we assume that these rays have penetrated any considerable part of the shield the total energy of the burst totals up to some 10^{12} electron volts. The energies in ordinary chemical reactions are of the order of one electron volt. Hence this process offers the possibility of an astounding concentration of energy.

An hypothesis has been advanced that most of the rays received are of a secondary nature, being fragments of bursts which have occurred in the atmosphere. Evidence substantiating this hypothesis comes from the observation that the rate at which bursts of ionization are recorded by ionization chambers or Geiger-Müller counters can be increased by the application of shielding material in reasonable amounts above the apparatus. This has an effect equivalent to concentrating a considerable fraction of the atmosphere near the instrument, indicating that under proper conditions the atmosphere or other matter may become a source of secondary rays. This raises the possibility that the only thing measured by present types of apparatus may be secondary rays, the primary or burst-producing entities being possibly of a different nature. The measured intensity of ionization is found to decrease as the depth below the top of the atmosphere increases. This might result from the fact that the burst-producing entity in traversing the atmosphere loses energy and thereby its ability to produce secondaries is decreased.

At the present time our knowledge of the origin and nature of cosmic rays is limited to relatively meager data concerning the variation of the average ionization with elevation, its value at different locations on the earth's surface and the burst-frequency and burst-magnitude relationships at different elevations. This is in no way due to lack of interest in the problem. The subject awaits the development of superior instruments and probably a fresh method of attack which will bring before us a clearer picture of the primary phenomenon involved as well as more detailed information relating to what actually happens when secondary effects occur.

Thus it can readily be said that the cosmic-ray burst phenomenon remains unexplained, though possible hypotheses exist concerning it. Among these may be the correct one, but for the present our knowledge is insufficient and the data too conflicting to indicate conclusively where the truth lies. So long as the present wide-spread attack on this problem continues it is probable that some day we shall understand better the mechanisms involved, and perhaps benefit thereby.

"MAN AND NATURE"—A CONTEMPORARY VIEW

By Professor WALTER P. TAYLOR
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FOR a couple of thousand years or more farsighted observers have been impressed with the changes man is making in his environment.[1] A new earth is in process of coming into being, so far as the things man can affect are concerned. What kind of a world will our children have to live in? As a partial help in answering this question let us list some of the things for which man is responsible.

GRAZING

Before man came on the scene the multitudinous grazing and forage-feeding creatures, bisons and other ungulates, rodents and insects, were relatively well balanced with the vegetation. Fluctuations took place, of course, but in the long run grazing pressure and forage resistance were equal. Man's activity in bringing onto the grass country vast numbers of domesticated stock—cattle, horses, sheep and goats—marks the beginning of a new story of the range. The animals were bred in numbers. Feeding methods were improved, water developed, trails, roads and railroads built, and large areas of range made more accessible. In many cases, keen competition and general economic conditions mean stocking on a basis of "all the traffic will bear," and more. Heavy grazing is not confined to the ranges of the western United States, but is in evidence in the East as well. Nor have the effects of over-grazing been confined to North America.

Buttrick[2] has shown that the lack of adequate regulation of grazing has resulted ". . . in the treeless countries surrounding the Mediterranean Sea, the moorlands of Scotland and England, the poverty and desolation of Spain." During historic times grazing is asserted to have been the cause of vastly more forest destruction than commercial lumbering. In England, under a system of stock-grazing in the royal forests, first the game began to disappear and then the timber. Insistent over-grazing in France resulted in such decline of resources that the number of sheep, from 1852 to 1913, decreased over 50 per cent. Human population in mountain regions, in approximately the same period, decreased more than 2,000,000.

In a review of Unwin's "Goat Grazing and Forestry in Cyprus" (Crosby, Lockwood and Son, London, 1928) Buttrick[3] quotes from a high forestry official that from the goat the Cypriot gets ten shillings worth of produce in a year and over a pound's worth of damage. He cites a statement by Sir Joseph Hooker that the goat is one of the chief enemies of mankind. Personal observations on the Navajo Indian Reservation in the southwestern United States makes the writer wonder whether later events will not abundantly confirm Hooker's opinion.

The magnitude of the grazing problem has been pointed out by Barnes.[4]

[1] See Lowdermilk, *Jour. Forestry*, 32 (5): 532, 1934; see also Marsh, "The Earth as Modified by Human Action," pp. xxiv + 629, New York, Scribners, 1898; and Ritchie, "The Influence of Man on Animal Life in Scotland," pp. xvi + 550, University Press, Cambridge, 1920.

[2] *Amer. Forests*, 32: 67–68, 124; 156–159, 190–191; 217–220, 228, 253–256; 293–297, 315, 316, 318–319; 359–362, 377–378, 1926. See also *Jour. Forestry*, 24: 141–152, 1926.

[3] *Jour. Forestry*, 27 (3): 294–296, 1929.

[4] "The Story of the Range," pp. 60, reprinted from Pt. 6, Hearings, Public Lands, U. S. Senate, 69th Congress, 1st session, 1926.

About 586,000,000 acres, it appears, or nearly one third of the total land area of the United States, is arid or semi-arid, valuable only for range and pasturage purposes. Of this land, approximately 186,000,000 acres are public domain. Barnes says ". . . it is so badly over-grazed as to be more of a liability than an asset." The total of land in the United States used for grazing, excluding crop lands pastured part of the year, is about 1,055,000,000 acres, or 55 per cent. of the area of the country.

Recently a series of destructive dust clouds swept over nearly half the United States. According to the Forest Service,[5] these storms originated largely on over-grazed semi-arid lands and former cattle ranges plowed for wheat near the east side of the Rocky Mountains. The dust from the midwestern states blew as far east as the Atlantic Ocean. E. A. Sherman, of the Forest Service, said:

> This is the way deserts start. Excessive grazing, which destroys the protective vegetative cover and permits the ground to be trampled into dust, and the plowing of naturally well-sodded grazing lands for grain crops make it easy for the wind to whip away the dry soil and develop into a destructive dust storm. Wind erosion on the plains is like water erosion in States farther east in its power to destroy rich land in a few years and to transform broad stretches of country into devastated badlands.

It is not a question, as some stockmen mistakenly think, of the country getting drier and the vegetation disappearing. Over-grazing does more than remove valuable forage; indeed, tends to alter many important environmental conditions. Accelerated erosion is promoted. Silting of nearby irrigation works and reservoirs is sure to take place. The soil becomes less favorable for the establishment and maintenance of valuable forage plants. The orderly trend of biotic succession is interrupted and the vegetation is thrown back into various less valuable vegetation stages.[6] A weed problem or a poison-plant problem develops on the over-grazed range. Difficulties with insects, game or rodents are more likely to be encountered than where the normal grass cover is maintained. As Barnes points out, over-grazing, since the earliest records of history, has meant disaster to the live-stock owner as well as the community.

[5] *Science,* May 25, 1934, p. 473.

[6] Sampson, *U. S. Dept. Agric. Bull.* 791, pp. 65, 66, 71, 72, 1919.

Fire

Under original conditions fires in the forest and on the plains occurred at intervals as a result of lightning. Some of the harmful effects of these ancient fires can be recognized even to-day by forest ecologists. The country was big, however, and the inhabitants few. If one section was devastated, the aborigines could move to another.[7]

The coming of civilized man was the signal for a tremendous increase in forest and prairie fires. Some fires were kindled on purpose, others by accident. However they begin, forest fires are now recognized as of high rank among devastating forces liberated by man. The complicated civilization of modern times is so dependent on the wood, grass, soil and water of forest and range areas that an extensive forest fire is likely to be a disaster comparable with a conflagration in a town or city. Indeed, a forest fire may be more serious than a fire in a city. For the city can be rebuilt with relative ease and speed, while soils, forests and watersheds can often be restored only with extreme difficulty, if at all; and such restoration requires a very long time.

Studies in California have conclusively shown that fires interrupt the normal course of succession. One of the

[7] Dr. A. J. Pieters, of the Bureau of Plant Industry, writes (letter of March 13, 1935) that in the long-leaf pine country at McNeill, Mississippi, some cooperative work by the Forest Service, Bureau of Plant Industry, and the Bureau of Animal Industry showed that reasonable use of fire was advantageous to forage production and not harmful to the increase of long-leaf pine.

striking things about the pine region as a whole, as Show and Kotok point out,[8] is the great area of potential timberland now occupied by worthless brush, evidence of the enormous power of repeated fires to eliminate the forest. In another place, these authors[9] state that although in the study of plant environment little weight has been given to fire, even under natural conditions, nevertheless, in the California pine region fire has been a primary force in determining the succession of forest types. The general trend, with repeated fires, is from timber to brush to chaparral to complete destruction of the productive capacity of the site. Already by 1925, in California, nearly one acre of timberland out of every seven had been taken over by brush, as one result of past fires, and it was estimated that the timber which this land could have produced would be enough to run the lumber mills of the state for many years. Fires on a watershed tend to destroy the power of the area to hold the water and to let it down gradually to the valleys below. Denudation through fire promotes rapid runoff, floods, erosion, silting up of irrigation works and lowered water table. Some of these points were all too concretely demonstrated by the results of the terrific downpour of New Year's Day, 1934, above Glendale, Montrose and La Cañada, in the Los Angeles district, California. Fire having previously (in November, 1933) denuded the watershed of vegetation, the flood, laden with detritus, rushed down on the unsuspecting communities involved, carrying death in its wake and depositing tons of earth on the city streets.

According to Forest Service records there were in the United States an average of more than 156,000 forest fires annually in the five-year period 1926–1930, burning over more than 41,000,000 acres of land. Fire was an important contributor to the 81,000,000 acres of unproductive forest land which nature apparently can not reforest without assistance, if at all.[10]

Cutting of Timber

Several years ago Greeley and his associates[11] raised the question whether we ought to *mine* our timber resources, a process sure to lead to their exhaustion, or *crop* them, like other products of the soil. Already at that time, these leaders pointed out, the "mining" of timber in the United States had reduced the original stand from more than 5,200,000,000,000 board feet to approximately 1,600,000,000,000 feet of virgin timber plus 600,000,000,000 feet additional in culled and second-growth stands. Only a remnant of the original eastern forest of 681,000,000 acres—namely, 60.7 million acres—remained, while nearly half of the virgin forests of the West had gone (originally these forests totalled 140.8 million acres; at the time when Greeley and associates wrote, this forest had been cut to 77.4 million acres). Nor had it been found possible to use the cut-over land for agriculture. To-day, in the midst of a depression (1934) the problem is more exigent than ever, although masked by a seeming over-production.

From the ecological view-point the cutting of the timber is but a single incident in a long train of associated events affecting all the plants and animals of the area. In many cases lumbering meant clear cutting, with resultant elimination of forest plants, wildlife and soil. Future productivity of the land was seriously affected. Watershed values were modified. Secondary successions following cutting were always somewhat

8 *U. S. Dept. Agric. Dept. Circ.* 358, pp. 8–9, 1925.

9 *U. S. Dept. Agric. Dept. Bull.* 1294, p. 29, 1924.

10 See Greeley, Clapp, Smith, Zon, Sparhawk, Shepard and Kittredge, Yearbook, U. S. Dept. Agric., 1922, p. 84, 1923.

11 Yearbook, U. S. Dept. Agric. 1922, pp. 83–89, 1923.

different from the virgin climax forest. Under some conditions wild game was benefited, in others interfered with. Drastic change was the order of the day. We see the results of reckless lumbering in the tax-delinquent-lands problem. The writer has seen potentially productive mountain valleys in the Southwest lumbered off with little regard for the future, their settlers, living in the shadow of poverty and misery, engaged in a hopeless struggle against insuperable economic odds.

Well may we heed the prophetic voice of Marsh:[12]

> . . . the vengeance of nature for the violation of her harmonies, though slow, is sure, and the gradual deterioration of soil and climate, in such exceptional regions, is as certain to result from the destruction of the woods as is any natural effect to follow its cause.

It is of great moment that the present national administration (1935) in the United States is exerting strenuous efforts to stem the tide of deforestation and related wasteful practices and get us back on a basis of conservative use of natural resources based on conservation principles.

Accelerated Erosion

Erosion is an important natural process which has been in operation as long as the earth has existed in its present form. This is the "geologic norm of erosion," as Lowdermilk[13] calls it. Unfortunately, man, in some of his enthusiasm for getting ahead, has overdone his alteration of nature's arrangements, so that the natural erosional process has been disastrously accelerated.

In farm districts, cultivation of the soil, coupled with removal of the natural vegetation cover, often promotes accelerated erosion. In forest areas the removal of trees, usually associated with fires and overgrazing, has the same effect. On stock ranges, heavy grazing by cattle, horses, sheep and goats exercises a similarly far-reaching and often serious influence.

All over the United States and, indeed, throughout the civilized world, the harmful effects of accelerated erosion are being recognized as never before. Kotok[14] pointed out that experiments in California have shown that removal of forest cover by fire increases the surface run-off of water from fifteen to twenty times. Lowdermilk and others have found that forest litter figures importantly as a preventive of abnormal run-off. In the California experiments the eroded material was 2,300 times as great from burned plots as from unburned. Erosion is costing American farmers at least $200,000,000 per year, Kotok asserted. Constructive studies in this field by Bennett,[15] Lowdermilk and others have aroused the public to an earnest desire to do something about it all. Long ago Marsh[16] called attention to the alleged fact that in Upper Provence and Dauphiny, France, the augmented violence of torrents following clearing had swept away or buried in sand and gravel more land than had been reclaimed by clearing.

Burrowing rodents are sometimes responsible for serious erosion results. In every case observed by the writer, however, the original disturbance has been by man.

The consequences of accelerated erosion are well understood in the West, where the silting up of irrigation works, filling of reservoirs, clogging of top soil with accumulating sediment so that the soil "freezes" and will not take water, gullying, lowering of the water table and consequent progressive desiccation of affected areas are all too often noted. It is less realized that erosion has been an important factor in the decline of acre

[12] *Op. cit.*, p. 294.

[13] *Jour. Forestry,* 32 (5): 532, 1934.

[14] *Amer. Forests,* 38 (7): 399–400, 1932.

[15] Sci. Monthly, 27: 97–124, 1928.

[16] *Op. cit.*, p. 243.

yields of wheat in part of the wheat belt, of corn in extensive areas of the Middle West and of cotton in the South.

According to Knight,[17] as a result of a five-inch rain which fell in the Black Belt of Texas in May, 1930, the rich topsoil, from land planted to cotton on an average slope, was washed away at the rate of twenty-three tons per acre. At Spur Station, Texas, Bennett[18] reports (p. 112) that erosion on a 2 per cent. slope amounted to forty tons of soil material per acre with 27 inches of rainfall. In the fall of 1927, he points out, a single rainy period in northeast Kansas took off more than forty tons of soil per acre, the young grain being largely washed out.

The results of overgrazing and deforestation, as related to erosion, may be apparent at points far distant, both in time and space, from the site where the original damage is done. Thus accelerated erosion, resulting from a too thorough cutting of timber or too heavy grazing of live stock, may help to fill and render useless an irrigation reservoir or cause a flood in the lower country hundreds of miles away. Most of the destructive effects of over-grazing on the plant cover are registered during the driest season or the driest year. But the terrific floods so often resulting from a denuded watershed, and associated with an all-too-rapid silting up of the lower portion of the rivers, take place in the wettest season or the wettest year, often by many months or years removed from the particular period when the damage was actually done on the upper reaches of the watershed.

Farming

I do not wish to imply or assert that all man's activities in modifying his environment are harmful. Through farming, closely associated with invention and industrial development, man has distributed useful plants and animals throughout the world and has enormously increased the production of food and clothing. An interesting temporary result, in America at present, is that seemingly overproduction rather than shortage is one of the most pressing farm problems.

As one animal species among others on the earth man is highly successful. One criterion of biological success is population. With something like a billion and a half persons in the world, the population increasing and standards of living tending to advance, man exhibits a toughness and a vitality which places him in a position of unquestioned supremacy. His ability to speed up production of plants and animals is an essential element in his maintenance of this position.

The flowering of man's intellectual, artistic and political life also has been associated with his increasingly effective practice of the art of agriculture. The machine age has been registered in farming operations, as in other fields. Better machinery and more power have meant more rapid modification of the original environment—more sod broken and land plowed, more trees planted or cut down, more cotton, corn or wheat seeded or harvested, more hogs bred and raised, more rapid transportation of farm products.

There is in southern California a huge ranch where the production of hogs has been as nearly mechanized as it is possible to make it. One sees the new-born pigs in one series of pens. In other pens one may follow all ages up to the mature animal. Trains on the one side haul in carloads of garbage from the city for feed, and on the other haul out carloads of hogs to the market. Here is mass production of an important farm product, with a maximum of mechanical assistance and a minimum of man power.

We must continue to farm. But we

[17] Official Record, U. S. Dept. Agric., 11 (27): 153, 1932.

[18] Sci. Monthly, 27: 112, 103, 1928.

shall apparently have to pay increasing attention to the problem of "sustained yields." The soil, the water resources, the native vegetation and animal life must be conserved. The utmost of our ingenuity and technical insight will apparently be required. Agriculture must become less an art, more a science.

Our economic system is in process of being redesigned to place the emphasis on conservation rather than exploitation. The greatest rewards must be given, not to those who exploit our fundamental resources most successfully, but to those who, while maintaining high standards of production, take the best care of the renewable resources with which they deal.

Elimination of Native Plants and Animals

The elimination of native plants and animals takes place largely in three ways: (a) Occupation of the land by man and a resultant crowding out of native species; (b) harvesting of indigenous species for sale or for sport; (c) ridding the occupied area of plants or animals regarded as pests.

(a) The story of the dispossession from its original range of the American bison is well known. Similar disturbances of outstanding game species have taken place in other places. The aurochs of Europe, the beaver in England, the white rhinoceros of Africa, the marsupial fauna of Australia, all have a profoundly different status as a result of occupation of the land by man.

The tendency is for all the larger, more beautiful and more conspicuous creatures, those which for any reason catch the attention of the hunting public, *to go first.*

Both the primeval forest and the animals in it were regarded by early settlers in eastern North America as serious obstacles to their progress. Our sturdy and self-reliant ancestors resolutely cut down the forests over great areas, and in the process crowded out many of the forest animals.

The consequences of single disturbing acts may be far-reaching. When a plant is removed all the fauna dependent on it goes too—birds, mammals, insects and the lesser forms that dwell on or in its roots, bark or foliage. Similarly with an animal—all its parasites, within and without, are taken away when the animal disappears, along with any obligatory symbionts or commensals it may possess. Good riddance? Perhaps—but the process of disturbance, carried somewhat further, is followed by consequences one would not, perhaps, anticipate or desire.

For example, when a forest is removed, not only the trees, but the entire forest animal and plant population, numbering hundreds or possibly thousands of species, is quite likely to go too. Soil conditions are changed and even the microclimates affected. Removal of a dominant species of plant or animal is not a simple process of subtraction. Determination of what is left depends on a new appraisal of the total situation.

Of course other species tend to flow in to fill the gaps, but the new biotic community is different. It may be characterized by more brush, by more game animals of certain species, by a considerably increased number of insects, by a decidedly augmented rodent population.

The extent to which man's occupation has gone and the degree of disturbance of nature which has resulted are little realized. The changes for which our irrepressible species man is responsible are not confined to closely occupied areas. They extend even to the far-flung forested districts, to the plains, the mountains, the deserts and the waters of the sea. Man's exploitation reaches far beyond the sound of his voice or the touch of his hand at any one time.

(b) As with occupation of the land, so with *harvesting* the crops, especially the

natural products of trees, forage and wildlife, there is a large chance of permanent losses of native plants and animals. Many years ago it was found that native or natural products, such as wild game, are at a disadvantage under a system that puts the chief emphasis on making a great deal of money in a very short time. Under such a system, short-term economic necessity dictates procedure rather than future needs or scientific conservation.

Commercialization has so far as possible been eliminated from wild game. The trend is toward the removal of other fundamental natural resources, as the forests, from the field of unlimited competitive exploitation for private profit. Alert leaders now recognize that some more inclusive formula than immediate personal gain must be invoked and applied if wastage and irretrievable loss of natural resources are to be prevented.

One of the humiliating features of the situation is the thoughtlessness, the carelessness with which man has blithely addressed himself to the exploitation of these great natural sources of wealth. His attitude has put a premium also, not on the wise use of resources for the general welfare, but on monopolization by the most ruthless and acquisitive of mankind for the benefit of a limited number.

(c) Pest control has received a good deal of attention from an early period. In many localities man must still struggle hard for his very existence, against other living things that would kill him or feed upon him if they could. Some of the natives of India are reported to live in fear of the man-eating tigers, which still infest certain portions of that country. Everywhere man must do his best to control or eliminate disease germs. Certain species of insects are responsible for troublesome and costly difficulties. The brown rat and certain other rodents are destructive and dangerous. Of much less importance are the so-called predatory animals in our own country—although their work is often spectacular and of a good deal of importance in certain areas. Within a few days (June, 1934) a certain wolf in Arizona is reported to have killed a number of range cows heavy with calf, and consumed only the embryo!

Seemingly control should be applied with great caution. Premature or mistaken control operations may do much harm. Dr. A. J. Pieters, of the Bureau of Plant Industry (letter March 13, 1935), reports that the fight against alligators in Florida had resulted in a decreased supply of fish. This was entirely contrary to expectation. The alligators were found to prey mostly on turtles, which feed largely on fish eggs.

A similar incident in another field is cited by Stoddard.[19] The marsh hawk is the most numerous of the larger hawks of the Thomasville, Georgia, region. It was occasionally noted killing quail. But examination of approximately 1,100 pellets of the marsh hawk showed but four quail, while one or more cotton rats, a serious enemy of quail, were found in 925 pellets. Instead of being a quail enemy, as might be concluded from a superficial knowledge of the situation, "the marsh hawk is probably the best benefactor the quail has in the area."

There are three things that ought perhaps to be said about animal control. The first is that control is made necessary by man's inevitable disturbances of the natural balance that existed prior to his advent. The second, a corollary of this proposition, is that a great deal of costly control, whether of disease germs, brown rats, insects, rodents or predatory animals, can undoubtedly be eliminated as we are able to reestablish natural equilibria and employ scientific management. The third is that over-drastic control is likely to defeat its own object.

[19] "The Bobwhite Quail," Scribners, New York, p. 209, 1932.

Seemingly we could get along very well without some of the trouble-making micro-organisms that produce our all-too-prevalent diseases. But with the vertebrates, especially, the Biological Survey has come very definitely to the position that, except in the rarest cases, extermination is not desirable—indeed, that the best control is that where the maximum of protection is afforded with the least killing. It is increasingly realized that elimination of all the coyotes, for example, might complicate the rodent situation and make things worse instead of better.

Depletion of Fisheries

While it has been man's experience that in many places the game fishes of the terrestrial streams, rivers and lakes may easily become depleted, the sea, and the fishes of the sea, have often been regarded as symbols of inexhaustibility. Records for the last few years of the cod fisheries of the Atlantic and the halibut and salmon fisheries of the Pacific indicate the error of these notions. Man's over-fishing or fishing at wrong times of the year or in wrong years threatens the integrity even of this generous food resource.

Over-grazing and burning of forests contribute to fish depletion in streams through forests and range lands: over-grazing by promoting turbidity of the water, forest fires by conditioning the addition of chemicals to the water which are poisonous to fish.

Pollution of waters is a major difficulty in industrial areas, as in Illinois and New York, where the problem has received much attention. The liberation in streams and lakes of the chemical wastes from industrial operations, of sawdust, sewage and miscellaneous materials has an exceedingly destructive effect not only on fishes but on fish food as well as on other plants and animals.

Pollution of lakes and bays along the seacoast by sewage and industrial waste products also has a bad effect on a number of aquatic organisms. In some instances oyster beds have been seriously affected by pollution.

Closely related to the depletion of fisheries by pollution are the unfortunate effects on sea birds of the release of oil on the waters by tankers or other vessels. The oil clogs the feathers of many species of these birds, eventually causing their death.

Drainage

Drainage affords an excellent example of the complete removal of an original habitat, with practically all the plants and animals in it.

The late Dr. E. W. Nelson, former chief of the Bureau of Biological Survey, and following him, Paul G. Redington and Dr. J. N. Darling have shown the extent to which our waterfowl are affected for the worse by unwise drainage projects. At the fifty-seventh annual meeting of the American Forestry Association Redington[20] asserted that as a nation we have been dealing with our marshlands much as we have with a great many other natural resources, acting first and considering the consequences later. He pointed out that the census figures for 1930 show that drainage has taken away from our waterfowl, in whole or in part, approximately 77,000,000 acres in the continental United States. While some valuable additions have been made to farm lands, there have been many rank failures. On tens of thousands of acres, asserted Redington, no success in farming has been achieved and many drainage districts are heavily in debt or even defunct.

Every drainage project eliminates certain natural fish, game, recreational and fur or other resources in the hope that others (usually agricultural) will be of greater value. In many instances the

[20] *Amer. Forests,* 38 (7): 400, 412, 1932.

original resources have proved to be more valuable than the newly developed ones.

When drainage of a natural marsh area is proposed, the only business-like procedure is to make a bio-ecological appraisal of resources to be affected and as adequate a comparison as possible of present and anticipated future values, in the light of all available information and of drainage experience in other places.

Irrigation Agriculture

An ideal of man for many years and in many places has been to "make the desert blossom like the rose." Some of the most productive of the world's farm lands, as in the Salt River Valley, Arizona; and in Imperial, Los Angeles and Fresno Counties, California, the valleys of Mesopotamia, the Nile, and numerous others, exemplify some present-day possibilities. In other localities success has been less apparent. Where the supply of water for irrigation has been of fluctuating character or insufficient; where the soil or climate has not been suitable; where the right crops were not used; where pests from nearby wild lands have been too much in evidence and have not been economically controllable; or where distance to markets was too great, irrigation enterprises have not paid.

Irrigation projects may be compared with drainage. In both cases the original habitat is almost completely altered and a new biotic community introduced. The resulting situation is completely artificial. Both irrigation and drainage are extremely expensive. Usually the sites are at some distance from markets. In both cases the land must be suitable for growing crops. If there is too much alkali in the soil in either case, failure will result. The risks are great. Just as the waterfowl, fishes and some of the other aquatic forms represent a real resource that is lost in drainage enterprises, so the forage plants of arid localities are valuable for grazing, and the wild game for recreational use. The real value they represent is likely to disappear when the land is "reclaimed" and brought under an irrigation project.

According to our present economic arrangements local over-production is obvious, and extreme caution should be exercised in either draining or reclaiming wild lands any further. A sharp alteration in national policy seems to be called for.

Ordinarily the natural production of an area, as forage and wild game on a grazing range, is reliable and may be counted on. But the maintenance of irrigation agriculture offers numerous difficulties. Unless there is a way to get rid of waste water, the water level in the soil may rise unduly, evaporation take place, chemicals accumulate, the soil become waterlogged and often alkaline in character. Fine-grained soils sometimes become sealed up by sediment in the irrigation water so that in the end the water stands on top of the ground and will not sink in. There is a question whether any great irrigated land area in the world except that lying under the Nile (which has the advantage of alternate flooding and drainage) has been kept in continuous production indefinitely.

As Thornber[21] says:

> . . . the natural tendency of all our arid lands is to revert to their natural desert condition, and nothing but the most intelligent efforts of man can prevent this.
>
> In the history of mankind this fight against the slow forces of nature in arid countries has been a losing one, and, except in the Valley of the Nile, where irrigation has been carried on under peculiar conditions, we have yet to find a single example of a permanent irrigation agriculture.

Neither drainage nor irrigation should be planned on lands which are already of

21 Univ. Ariz., Ag. Exp. Sta., *Tech. Bull.* No. 6, foreword, January 15, 1926.

value for recreation, forestry, grazing, or wildlife production unless substantially increased returns, as shown by comprehensive scientific and economic studies, are reasonably well assured.

Vitiation of Air

While the extent to which man can affect the total atmosphere is limited, nevertheless some results of industrial operations may be far-reaching. The fumes from smelters, which contain sulfur dioxide and perhaps other poisons detrimental to plants, have often ruined nearby vegetation, especially browse and trees. Grass seems to be much less affected than certain other species. The pall of smoke and other cloudy substances that hangs over most of our industrial districts must exercise some effect on the plants and animals that have the misfortune to be subject to its influence, though the writer has seen no convincing studies of the subject.

Stocking and Restocking Enterprises

By "stocking" is meant the carrying of animals or plants from their natural habitat to some other; by "restocking," the reintroduction of a species where it once occurred naturally.

A moment's consideration will show that reactions of unusual importance have taken place as a result of stocking enterprises. I need only recall the case of the European rabbit in Australia. Other well-known cases are afforded by the introduction of the American gray squirrel into England, the muskrat on the continent of Europe and the English sparrow and the European starling into the United States. The introduction of pigs on Mauritius and Rodriguez Islands is said[22] to have brought about the total extirpation of the dodo and solitaire, respectively. Goats were introduced on St. Helena in 1513. In 1810 it was realized that this "precious oasis of tropical plant life" in the midst of the Atlantic Ocean had become a barren and rocky waste. The forests were gone, leaving no successors.

In some of these instances, particularly, the original biotic community has been shaken, disturbed, well-nigh destroyed. Previous to the introduction one could scarcely have anticipated its far-reaching consequences.

It is true, of course, that most of our agriculture is a process of "stocking." Excellent producers of food or materials for shelter are discovered among the plants and animals of the world. Farming domesticates the animals, cultivates the plants and distributes them both wherever they will grow. The small grains, corn, alfalfa, the domestic fowl, the dairy and range cow, the horse and the hog are cases in point. This process of scattering valuable products has contributed mightily to the ascendancy of man, as already pointed out. There *are* some advantages to civilization.

But along with the beneficial phases of introductions have gone some interesting cases of involuntary importation, as of plant pests and parasites—white pine blister rust and chestnut blight; household pests—the brown rat and the house mouse; diseases of man and other animals — bubonic plague, smallpox; harmful insects—as the corn-borer, Mediterranean fruit-fly and Japanese beetle in America, and the Colorado potato beetle in Europe.

It is obviously of vital moment to the citizens of the United States that introductions shall be of the right kind. On one side the Government maintains a small group of agricultural explorers who comb the earth for improved varieties of plants. On the other the Government finds it necessary to set up what is virtually a "plant and animal immigra-

22 Ritchie, "The Influence of Man on Animal Life in Scotland," Univ. Press, Cambridge, 1920; reviewed by Detwiler, *Jour. Forestry*, 28 (1): 80–82, 1930.

tion service'' along our borders, where the U. S. Bureau of Entomology and Plant Quarantine exercises rigorous surveillance over all incoming plants. The importation of animals likewise is carefully regulated under the Lacey Act, administered by the U. S. Bureau of Biological Survey.

Problems of stocking and restocking come strongly to the fore in fish and game administration. The former tendency of sportsmen and their representatives almost everywhere was to bring in game birds or mammals from somewhere else. At present progressive sportsmen are trying to get the states and the Federal Government to concentrate all possible resources on the maintenance and increase of valuable native species. It is true that some successes have been recorded in the introduction of game—especially of the ringnecked, or Chinese, pheasant—in England and in many states of the United States. Probably the overwhelming majority of game introduction projects, however, have resulted in failure and waste of the sportsman's money.[23]

An essential preliminary to any proposal for game importation or any sort of ''stocking'' should be a detailed ecological study of the species at home, with special reference to its habits and habitat and the conditions it will encounter in its new location.

While the burden of evidence is against the importation of foreign game, the bringing back of species of game formerly occurring in an area is another story. Even in these cases it is essential for success that certain precautionary studies should be made prior to the event. The habitat ought to offer reasonable chance of survival—if the original forest is lacking there is little excuse for restocking forest game. If the grass and food plants have been grazed off there is no hope for success in bringing back grass-inhabiting species. The conditions as regards food, shelter and maintenance must be suitable. If agriculture has grown up about a mountain range so that reintroduction of elk, originally present, would be attended by difficulties to the residents, restocking should not even be attempted. It goes without saying that animals used for stocking or restocking purposes should be free from disease. Other important points are to liberate a sufficiently large number of individuals to give some hope of their survival, and to give them legal protection at least until they become established.

Fishes of various kinds can be handled much more economically and practically than, for example, game birds. Following the discovery of the possibility of the hatchery method of propagating game fishes, stocking and restocking suitable waters has become routine practice wherever conservation departments operate.

The chief weakness in the whole problem of the transfer of plant and animal species is an imperfect knowledge of their ecology, and, in some cases, failure to use available data. More high-quality information and an increased reliance on specialists would go a long way toward saving funds and really conserving and increasing our resources. If a tithe of the money that has been spent on fruitless restocking enterprises had been used for scientific research and its applications, it is safe to say that we would possess substantially larger numbers of game animals than we do at present.

Preservation of Game

A few years back one would scarcely have anticipated that over-protection of game would become a difficult and troublesome problem anywhere in America. But such is now frequently the case.

A notable instance is afforded by the Kaibab National Forest, in northern

[23] Those interested should consult the long list of attempted game introductions given by Phillips, *Tech. Bull.* 62, U. S. Dept. Agric. pp. 1–63, April, 1928.

Arizona, already widely discussed in the literature of conservation. As shown by this striking episode, game surpluses may exercise an exceedingly detrimental effect on the vegetation of their habitat, which of course means ultimate serious consequences to all animals and to the soil. Clepper[24] asserts that deer in Pennsylvania have increased to 800,000 head in 40 years, which is three times the optimum carrying capacity of the forests. In many localities they have destroyed the undergrowth, including mountain laurel and rhododendron, effectively prevented natural forest reproduction and even destroyed extensive plantations of various hardwood and conifer species. Over-population has also led to decrease in deer size and vigor, and has also, by destroying their food and cover, greatly reduced the population of small game. Remedies suggested include the reduction of the herd, the shooting of does and the promotion of better distribution of deer through the forested parts of the state.

Ultra-preservation of game, as on the Kaibab, changes the habitat and may affect all the plants and all the other animals. The potential seriousness of carrying a good thing too far has been little realized in the past, but is now receiving consideration in many places. Neither ultra-protection on the one side, nor extermination on the other, is desirable. Scientific wildlife management, considering the needs of the entire biotic community in its environment, is increasingly realized as the proper objective. Any management worthy of the name must include the possibility of reduction as well as increase in the resource under consideration.

The Balance of Nature

Many scientists have apparently become somewhat skeptical regarding the existence of any balance of nature. In one sense there never was such a balance. Nature is not static and never was. It is wholly normal to expect wide fluctuations in numbers of plants and animals, considerable swings of climate, back and forth, and ample variation in all characteristics of individual, species, community and environment.

But in another and a very real sense the balance of nature does exist and is one of the important features of organism and environment. As has been previously pointed out, just as in physics and chemistry, for every action there is an opposite and equal reaction, so in the living world. When more is added here, something is subtracted there. The balance of nature is a fluctuating relationship between the organisms of the biotic community among themselves and between the biotic community and its environment.

It is true that all the modifications of his environment by man that have just been considered tend to change the natural balance. The old balance, existing before man came on the scene, is gone forever. A new balance, however, has been struck. More accurately, new balances are being struck in each succeeding interval of time, since conditions are never twice the same.

It is inevitable that man should so far as possible order nature to suit himself. Every other living creature tries to do the same. There is no reason why any former condition of things should be perpetuated. Indeed, with the increase in numbers and activities of mankind the old balance of the caveman days or prehuman days is as undesirable as it would be impossible. Even if man were not a member of the world fauna, the balance would continuously fluctuate.

But man does have some obvious responsibilities in reference to the natural balance. His modifications of nature

[24] Pa. Dept. Forests and Waters, *Bull.* 50: 5–45, 1931.

should be so carried forward as not to make the new balance harmful to him. That is why the people are turning increasingly to the better regulation and control of their common natural resources, whether they be minerals, forests, wildlife, forage, soil or water. Pertinent to this discussion are the following gems from Trader Horn's philosophy: "Aye, the balance of nature—leave it alone and it'll function to perfection." "And believe me, when man has destroyed nature then it's his turn to go."

In order to be constructive, it is often necessary to be critical. The whole weight of commercial operations and the profit system is inevitably on the side of short-period exploitation of natural resources. While the writer has no intention of leaving the impression that proper use of the things around us is harmful, he feels that increased attention to some of the present and future consequences of our actions is absolutely essential.

Through unremitting research, concentrated intelligence, courage and unselfish cooperation, man must attain a place where he is not destroyer, but master-manager-conserver of natural resources. This objective he must win to insure his own survival. He must avoid over-specialization, while at the same time he learns more about each department of nature. He must exalt the view of nature as a unit and make his management programs conform to the needs of this larger and more adequate outlook.

Somebody once suggested a moratorium on research, but such a moratorium would mean retreat to a régime of scarcity and a lower standard of living. Enlightened research, in the social and economic fields as well as in natural science, and its applications are the most important activities in which man can engage. Our trouble is not too much knowledge, but too little. There are no surpluses of intelligence, courage and unselfishness.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE STORY OF ORE DEPOSITS

By Dr. EDSON S. BASTIN

PROFESSOR OF ECONOMIC GEOLOGY AND CHAIRMAN OF THE DEPARTMENT OF GEOLOGY, UNIVERSITY OF CHICAGO

YOU of the radio audience are listening to this broadcast through sets built of many different kinds of metals. You know perhaps that these have come to your home from mines in the remote corners of the globe—from China, from the Malay States, from South Africa and perhaps other distant places. To-day I would like to tell you something of the ways by which nature created those treasure houses of the metals that we call our ore deposits in which our mines are located.

The winning of nature's secrets requires acuteness and patience. This is true even of those processes which can be watched and studied from their beginning to their end, but it is especially true of many of the processes with which the geologist is concerned. Most geologic processes proceed at so stately and leisurely a pace that the span of man's life is far too short to compass them in their entirety and he is forced to fit together isolated observations like the fragments of a jig-saw puzzle to form a complete picture. Experiments in the laboratory, imitating the natural processes in miniature, speeding them up and giving them continuity, may, however, furnish a useful check on the conclusions from such scattered observations out-of-doors.

In the solving of other problems the geologist is under even more serious handicaps. Many of earth's processes are not visible at all to human eyes but take place deep within the earth far beyond the reach of the deepest mine or even of the deepest drill holes which probe to depths of more than 12,000 feet. There can be no hope of ever seeing these processes in action, but the slow wearing down of the earth's surface by the rain and the rivers finally reveals to us the effects that they have produced, as the paring of an apple may make visible a hidden blemish. In such cases the geologist, like a detective who did not see the crime he is set to solve, must rely wholly on circumstantial evidence and deductive reasoning.

The processes by which most of the ores of the metals have been formed are in this difficult class, and so it has happened that, in spite of its practical importance, ore formation has been one of the last of the great geologic processes to be understood. Only in the past generation has there come to be much agreement in opinion concerning it, and even now we might feel doubtful of its solution had not almost all other possible explanations been tried and discarded because they failed to fit the facts.

The explanation that has finally emerged through centuries of trial and discarding of theories, dating back to the Middle Ages, seems at first acquaintance not especially plausible, but we must recall that nature often creates strange bed-fellows. Our metal mines do not usually associate themselves in our thoughts with volcanoes. Yet to-day the evidence is clear that most ore deposits are products of ancient volcanic

action or, as the geologist calls it, volcanism. But why, you may ask, has such a partnership between ore formation and volcanism been so long a mystery, since we have learned to know and understand so well the spectacular processes displayed at Vesuvius, at Etna and at hundreds of other volcanoes scattered widely over the earth? The answer is that the formation of ores is not associated with those phases of volcanism that appear at the earth's surface in volcanoes and their attendant phenomena. Had such been the case we should long ago have understood their origin. Rather, the ores are related to those kinds of volcanism that only occur deep below the surface and find expression in the slow cooling and solidification of deeply buried masses of molten rock material. Many lines of evidence have led to this conclusion of the partnership between ore deposition and deep-seated volcanism.

The fact is that by and large, and making one allowance for certain ores that clearly have a different origin, regions of ore deposition are also regions of volcanism. If we compare two maps of North America—one showing the distribution of igneous rocks and the other the distribution of ore deposits—the maps are nearly identical. In the United States, the West from the Rocky Mountains to the Pacific is our great mining region, and it is there also that volcanism —ancient and modern—occurred on the greatest scale.

Again, some ore deposits are observed to pass by the most gradual transition into common and familiar rocks that we well know, solidified from a molten state. If one was once molten, the other must also have been. The chromite deposits of far-off Rhodesia, from which come the glint and glitter of the chrome plating on your car, are of this class of deposits.

But not many ores formed within the very heart or center of volcanism as did these. Most of them lie not within the volcanic rock itself but close to it in the bordering rocks—and of this sort are nearly all our mineral veins. Obviously, these ores are not themselves metal-rich volcanic rocks as were the chrome ores. They have been deposited by metal-bearing solutions exuded from the volcanic rocks into the bordering rocks where they deposited their load of metals.

One of the most convincing evidences that ore-forming solutions have been given off from volcanic sources is furnished by the Braden mine in Chile. There above timber-line in the high Andes is a colony of American mining engineers who have developed one of the largest and in some respects the most unique copper mine in the world. There nature, using the rivers as her carving tools, has sculptured the earth's surface with bold strokes, cutting on the bias a section through an ancient volcanic vent and exposing it like a gigantic open book for the geologist to read. The ancient volcano is the Braden copper mine, and when the geologic story is unraveled it is found that at the site of the old volcanic vent there came repeated alternations of volcanic activity and ore deposition: first rising mineralizing solutions, then volcanic eruption, then rising solutions that formed copper deposits, then renewed volcanic activity and finally more copper-depositing solutions. All were confined to the old volcano or its immediate vicinity, and the conclusion is difficult to escape that all came from the same volcanic source. Thus was developed one of the strangest copper mines of the world—a hollow cylinder of copper ore occupying the periphery of a vent wracked and shattered by volcanic explosions. It is possible for the miner to travel underground for miles in these mine workings, making the complete circuit of the old volcanic vent and returning to the point from which he started.

It is not needful, however, to travel to

Chile to find ore deposits closely confined within an old volcanic vent. One of the famous gold camps of our own West is Cripple Creek in the Rockies of Colorado, easily reached by a scenic highway from Manitou. There an old volcanic vent two miles across has been sliced nearly at right angles by erosion. The gold-bearing veins that made this camp famous are all within the filling of the old volcanic throat or in the immediately adjacent walls. Deposition of rich gold ores followed close upon the heels of volcanic action and both rose from the same deep source.

In a very few mines the processes that formed the ores still seem to persist in a feeble and impotent way. At the great Comstock Lode at Virginia City, Nevada, whose palmy days were so vividly pictured by Mark Twain in "Roughing It," the waters in the deeper workings 3,500 feet below the surface were hot enough to cook eggs and scald flesh and the miners often worked in 15-minute shifts with a hose of cold water playing on them. In these waters the chemist finds small dissolved amounts of the metals. They seem to be the dilute successors of the hotter and more concentrated waters that deposited the ores.

I have tried to give a picture of the processes by which the majority of ore deposits have been formed deep within the earth. When, however, erosion has stripped off their covering and exposed them at the surface they are opened to the chemical attack of the gases of the air, to the dissolving action of percolating rain-water and to the wash of streams—in short, to all those processes which the geologist calls "graduation," by which some parts of the earth's surface are worn down and others graded up. Thus is begun a second chapter in the history of many deposits of the metals. If the worthless components of an ore deposit are dissolved by the surface waters and carried away, the part that remains behind, being no longer diluted by them, becomes proportionately richer in valuable metals. This was the secret of the extraordinary richness near the surface of many of the gold veins discovered by the prospectors of the golden 50's in Colorado and California—a richness never duplicated at greater depths. Some of the gold from the rich outcrops of the veins is likely, however, to be washed down the hillsides and accumulate in the gravels of the neighboring stream beds to form the placer deposits that yielded their treasure so abundantly to the forty-niners through simple methods of surface mining.

Not infrequently the effect of the air and surface waters is quite the reverse of that which has just been cited, for the valuable components of a deposit of the metals may be the ones dissolved, leaving the worthless material behind. The valuable metals thus dissolved may be carried away and scattered beyond the possibility of recovery, but fortunately in many cases they are reprecipitated in deposits rich enough to be worked. At Butte, Montana, the greatest copper camp of the United States, copper dissolved from the outcroppings of the veins was reprecipitated deeper down within the veins making them richer than they were originally.

Under other circumstances the metals dissolved from ores or even from ordinary rocks of the land surface may be carried to the ocean, there to be precipitated as metal-bearing sediments. In such a manner were formed the large iron ore deposits of Birmingham, the great steel-making center of the South. Thus in nature's laboratories have gone on the natural processes of concentration of ores that have made the metals available for our human needs.

ASTRONOMY AS A HOBBY

By Dr. OLIVER JUSTIN LEE
DIRECTOR, DEARBORN OBSERVATORY, NORTHWESTERN UNIVERSITY

REAL avocations or hobbies usually *elect themselves* into the conscious life of an individual. They often come into a person's life in much the same way that an unexpected comet comes into visibility in the sky, as a faint nebulous idea or notion oozing into consciousness like so many other peripheral mental products that pass in and out our minds. Then the idea grows into a definite program or interest. Cultivating a hobby is a real educational activity.

An ideal hobby ordinarily has no connection with a person's vocational or professional work. You are all familiar with specific cases. The following are typical examples of hobbies: Dr. Whitney, director of all the vast research operations of the General Electric Company, raises and studies turtles. Mr. Haaland, a farmer and orchardist in Door County, Wisconsin, is an authority on the ancient Norse explorations and rune writings in the North Central States. Dr. Harlow Shapley, director of the important Harvard College Observatory, finds time to study and write about the lowly but interesting ants. Dr. Graham Laing, professor of economics at the California Institute of Technology, makes with his own hands all sorts of small, serviceable tables in the modern style and gives them to his friends. President Roosevelt and King George of England are both enthusiastic collectors of stamps. Robert E. Millard, flute soloist with the Symphony Orchestra in Portland, Oregon, has built himself a small, but very attractive observatory, and owns several small telescopes with which he is making observations of variable stars and of occultations of stars by the moon. These observations are valuable. The list is almost infinite in length and in variety.

Hobbies are often adopted quite deliberately and consciously. This choice is usually accomplished with much less strain than is present in the choice of a vocation or a profession, which has so many complicating circumstances tied to it—native ability, financial return, social status, opportunity in a competitive world and many other aspects of life have to be allowed for. And unfortunately many people are not happy in their life work. Therein lies a tremendous difference. Every one who has a hobby is happy with it, loves it.

Now frankly, wouldn't the whole world be a different world and more interesting and satisfactory if all the activities in it were regarded as hobbies and every one were permitted to do his part with the enthusiasm and the joy which men have always found in pursuit of a hobby. And we should not need to worry that any of the work of the world would be left undone. With machines being developed for doing almost all the drudgery and most of the really disagreeable tasks connected with living, I venture to say that some one could always be found who would really enjoy doing any one of those jobs which remain to be done in person. The one essential quality common to all hobbies is that they take a person's mind away from his usual work. Just how far away depends upon the mind and personality of the person in question. The examples I gave at the beginning, Dr. Whitney and his turtles, Mr. Haaland and his runes, and so on, illustrate this point.

The history of astronomy through the ages shows that this old science has attracted to it the utter devotion of a great many amateurs, who have contributed immeasurably to its progress, besides af-

fording these men the greatest satisfaction in the cultivation of this avocation or hobby.

To mention only a few: The great Sir Isaac Newton was for the last thirty-one years of his life, 1696 to 1727, the director of the British mint, so that his scientific activities during this period were, in a sense, those of an amateur. In 1857 the Gold Medal of the Royal Astronomical Society of London was awarded to a middle-aged druggist, Schwabe at Dessau, Germany, for his thirty years of observations of sun-spots, and for his discovery of the eleven-year cycle in sun-spot activity—a most important discovery. Our own great Sherburne Wesley Burnham, for more than a generation the leading observer of double stars in the world, was successively a court reporter, clerk of the United States Circuit Court at Chicago and for five years receiver for the Chicago and Northern Pacific Railroad. His astronomical work during these years brought him international recognition.

Astronomers often hear the question "How do you get started in the study of the heavens? The objects in it seem so unreachable." The answer is simple. "Start with elementary phases of the subject. And remember, that most of the elementary considerations are also fundamental."

To put it concretely, you first need interest in or, if you please, curiosity about the great universe. Then you need more interest and a star chart. By the time you have located the North Star or the Great Dipper in the sky and have identified it on the star map your interest will increase spontaneously and in a few evenings you will be able to identify and name the brightest stars in the sky and most of the scattered groups of stars which we call constellations. By this time you will have or will want some up-to-date text-book on astronomy. And remember this—you do not need to know any mathematics beyond common arithmetic to enjoy astronomy and in many branches of this science you may even do important work without using or needing the higher branches of mathematics.

At this point you will want to look through a telescope at some of the fascinating objects in the sky, the moon, planets, double stars, star clusters and nebulae. Most colleges and universities have telescopes which may be used. Then there are many enthusiastic amateurs, all over the country, who have made their own telescopes, which they are always pleased to demonstrate.

After having had the experience of observing with a telescope you are capable of doing any one of a number of things. For example, you may buy a small telescope or you may set out to make your own telescope. If you are mechanically handy, you can, in the course of a few months, make yourself a reflecting telescope of considerable size, at a really very small outlay of money. May I interject here the statement that if you will send a request to Dearborn Observatory, Northwestern University, you will get, without charge, a list of books and other aids which will start you on your way to make astronomy your hobby.

I think of an avocation or hobby as involving constructive activity. For example, just reading about Navajo blankets does not seem to me to be a hobby, while collecting Navajo blankets or writing the story of how and why they are designed as they are, does. Similarly, just reading astronomy is hardly an avocation, but if in addition you should set out to construct a fine star map or a celestial globe with colored chips of glass for stars, or to make a telescope yourself, or settle down to a program of observing variable stars, mapping the paths of meteors or observing the changes on the face of the giant planet Jupiter, then I should say you are making a real hobby of astronomy.

It is probably safe to say that several hundred men in this country are making

telescopes for themselves right now. A considerable number of these amateurs are making or will be making valuable observations, which are being published every month with full credit given to each observer. In the months of July and August of last year alone, 6,727 observations of 402 variable stars were made by 88 amateur observers scattered all over the United States and published in the October number of the journal, *Popular Astronomy*. In many of the leading countries there are Associations of Variable Star Observers whose members have gone about it so seriously and enthusiastically, and to such good effect, that they have practically taken over the whole field of observing the brighter variable stars. Nothing could please the professional astronomer more, for it has released his time for other work.

There are many portals by which men enter the fascinating house of astronomy. Those who try to come in through the reading of such authors as Eddington and Jeans find themselves at once in a long series of reception rooms, the first of which we may call Higher Mathematics, the second room, Classical and Modern Physical Theory. The third room, Philosophy, as done in the style moderne, is colorful but bewildering. As a matter of fact the partition between the two chambers, Modern Physics and Philosophy, has been somewhat noisily kicked down in the last few years. Much of the debris still lies about in both rooms, and the guest who tries to enter the house of astronomy by this entrance quickly loses his way and is quite likely to forget that the glorious panoply of stars, planets and nebulae are still shining, and inviting admiration and study. The haughty guards stationed throughout this entrance are not very friendly or helpful to the beginner.

There is another entrance, the most beautiful and dignified of all, the door of celestial mechanics. Here exists the finest order, the most elegant furniture, the sweetest peace. But the price of admission is mathematical power, and few men have that coin ready at hand. I would not, however, discourage you forever. There are several smaller entrances to the house of astronomy. We may call them cottage doors or garden gates. They lead almost directly into the charming center of the house, and there are no guards to prevent entrance. On the contrary, helpful guides are always at hand when they are wanted.

We may call one of these gates the Chart and Book. You are admitted at once to contemplation of the serene beauty of the heavens. After lingering a while in the outer spacious garden, you will notice another stronger gate, the gate of the telescope. To enter here, you must have a telescope. Having oriented yourself in this part of the house you will find a number of charming gates and stiles and walks leading to rooms or terraces which we may call the terrace of variable stars, the pergola of double stars, the garden of colors of stars, the tearoom of planetary study and the workshop of spectroscopy.

Sooner or later you will find the particular spot in this great house where you can always be happy with interesting and charming companions. There is not the slightest doubt that the world is coming into a high tide of leisure for every man. Our industrial and social economy must be reshaped and adjusted to that idea. Many of us will simply sit and twirl our thumbs in unhappy idleness. Most of us will adopt or develop avocations, non-professional and non-vocational interests of some kind.

May I suggest that you enter the stately house of astronomy by whichever portal or door you prefer. Then express yourself in some activity. Use figures, diagrams, models, telescopes, verse or prose, but avoid barren speculation, until your hair has grown gray and your spirit mellow in the contemplation and study of the marvels of the heavens.

THE MEANING OF MATHEMATICS

By Dr. E. R. HEDRICK

PROFESSOR OF MATHEMATICS, UNIVERSITY OF CALIFORNIA AT LOS ANGELES

I SHALL try in the short time at my disposal, notwithstanding real difficulties, to tell you something of the meaning of mathematics. Mathematics arose early in human history; in fact, before there was written history. The necessity of counting and of simple arithmetic certainly existed in every primitive race. Its first form consisted in counting on the fingers and sometimes on the toes, as witness our own systems of counting by tens and by twenties.

Before any advance in civilization was possible, even more definite and conscious mathematical skill was necessary. Thus it is related that the ancient Egyptians were compelled to create some rules for land measurement on account of the shifting of boundaries in floods of the Nile River. Guesswork gave way gradually to definite established rules for measurement, and these in turn to very well-thought-out rules for such areas as those of triangles, quadrilaterals and circles. Such rules are reported, for example, in the famous and very ancient Ahmes papyrus. Before the pyramids could be built, quite accurate knowledge of geometric quantities and of simple surveying was necessary. Whenever such rules for areas, volumes and surveying are expressed in general terms, then algebra is born. For algebra consists fundamentally in general rules about quantities that are true in all cases, as opposed to the special instances of arithmetic.

Contrary to the too-common misconception of algebra, it is not necessary to use letters to represent quantities. It is the generality of the statements, rather than the manner of expressing them, that constitutes algebra. Thus the statement that the area of any triangle can be found by multiplying half its base by its height is an algebraic statement. The statement that a recipe for making a cake can be used to make a larger cake by multiplying each ingredient by the same number, and intelligent thought as to how this is limited by the dimensions of the oven, is certainly algebra, for it is quite general. Even such thinking does not occur to untrained minds.

From such simpler quantities, the world has advanced, as civilization has advanced, to more and more complex quantities. From the mere areas of ancient Egypt, we have developed intricate and extensive geometric principles and algebraic rules, until such complex quantities as the amount of earth to be excavated in the Panama Canal, the precise weight of a great bridge or a great ship, can be stated before the work starts.

From the humble household uses of ordinary life, we have developed mathematics until we can carry on such complicated operations as life-insurance, the amortization of bonds and mortgages, the understanding and control of nature and natural forces in the sciences that deal with measured quantities and in engineering.

More than all else, mathematics is (and of a right ought to be) a study of quantities and of the relations between quantities. Who is so bold that he will say that quantities (numbers, geometric quantities, business quantities, quantities in science and in engineering) are not fundamental to our civilization, to the lives of all of us? In a word, then, this is the meaning of mathematics: to know of quantities with which the world deals and to know the relations that arise in any of our problems. Thus house-plans involve geometric quantities of size and shape and form, be the house little or be it a great steel-framed office building.

These geometric quantities are connected with quantities of lumber, of cement, of nails and brick and mortar, with quantities of labor and wages; these again are connected with quantities of money and rates of interest, with discounts and with amortization of loans and mortgages. To face such questions, big or little, with understanding, each man should know, each woman, too, who deals with life at first hand, what are the relations between such quantities and how to deal with them.

Such situations, and thousands of other situations large and small, confront society and the individual on every hand, on every day of every year. If these and like things are not taught, it is the fault of the teachers, not of the subject; it is the fault of the educators, not of the fundamental basic parts of real education. In the words of Sir John Perry, "mathematics began because it was useful, survived because it was useful, and will continue because of its usefulness."

Despite this, some say that we may leave all such matters to the "experts": they—the "experts"—will do our problems for us. There are indeed experts in all kinds of quantities: experts in building, experts in business, in banking, experts in the lending of money on mortgages and on instalment buying, experts in home-loan societies and corporations, experts in insurance, experts on pensions, experts on taxation and on the evasion of taxation. I will not decry them as a class. Such wholesale denunciation of business men and bankers has been all too common of late, and I will not be party to it. The greater number, by far, are honest, upright, well-meaning, public-spirited. But, just as in the law there are shysters, just as in the field of medicine there are quacks, so also in the field of business and finance, in insurance, in pensions, in bonds, there are those unworthy of the great businesses which they disgrace, unworthy of protection by the honest business and professional men, as are shyster lawyers and quack doctors unworthy in their groups. It is all too evident that many such, unprincipled, ruthless, greedy, have preyed upon the very ignorance of mathematics (that is, of quantities and of relations between quantities), preyed upon the men (and the women, too) who have been told, perhaps, that they need no mathematics, since the experts will do it for them. Shall I repeat that some among the "experts" have "done" the people, rather than their problems?

What subject so touches life, the lives of all of us? The English language, perhaps: for it I ask your support as a basic fundamental of true education, quite as much as for mathematics. Besides this, what other? History? Law? Economics? How many millions are now struggling—many hopelessly, bitterly—with payments on mortgages and on instalment purchases, made at cleverly concealed rates of interest? How many of these hard-pressed millions of people even know now the actual rate of interest that they are paying? Have you such a problem yourself? Do you know what rate of interest you yourself pay? Do you know that rates as high as 30, even 40 per cent. have been charged by the more unscrupulous? If a radio whose cash-sale value is sixty dollars is sold for five dollars down and five dollars a month for each of twelve months thereafter (a total of $65.00), can you find the actual rate of interest paid? Is it within reason?

A private corporation, representing itself as a sort of agent for the National Housing Act, has recently circulated pamphlets that give the impression that it will lend money at 5 per cent. In fact, the corporation is not an agent of the government, and the actual rates of interest charged in examples stated in the pamphlet are nearly 12 per cent.

By comparison, would the debt-ridden millions have profited more by study of the battles of Napoleon, or even those of Pershing, rather than by a study of the

relations of ordinary interest on money? By a study even of the law of supply and demand, important as that is to us? By a knowledge of the manner of election of our judges or of the powers of federal juries? I mention here no little topics for your comparison; yet which of them can be compared in its direct effect on the lives of people with the mysterious ways of interest on money?

Interest, yes, and many another subject of wide and vital import—insurance, bond-payments, pensions, great buildings and small houses, payments on staggering international debts and your own instalment payments on that automobile of yours; these are based, all of them, on simple principles of mathematics that are taught in every high school, and they could be made clear to all if teaching were less formalized.

Modern science, the radio, electric power, gas-engines, automobiles, airplanes, all railroads, all great buildings, all great bridges, all questions of science that deal with measured quantities, owe their very existence in their modern forms to mathematics as to no other element in our education or in our progress in learning. No informed person will deny the entire truth of this assertion.

Notwithstanding this, there are some minor educational leaders, false to be sure, but often powerful, who say that mathematics has no relation to modern life: Is this then credible? Rather they who say it show only their own misconception of mathematics, or of life, or both. Shall the generation of boys and girls now in our schools know even less about the quantities with which the world works? Shall they—the coming generation—be even more at the mercy of the predatory fringe that disgraces business and finance? Has not our own generation learned sufficiently the folly of ignorance about the many quantities with which it has of necessity dealt, too easily misled by unscrupulous "experts"? Is not the present plight of the whole of society due to light-hearted ignorance of the quantities, sometimes vast beyond easy comprehension, as in the case of international loans, sometimes petty in single instances, as in the deceptive forms of cans used for canned goods? For example, does the public know even now that the orgy of instalment-buying in the late twenties amounted in fact to an inflation? Does it know that this is one of the direct causes of the depression?

Tell only those who have no life that these things are not part of life! Tell only those who are idle that our business is not affected! Tell only those who do not care that society and the individual are not concerned! Tell only those who wish to perpetuate fraud and extortionate usuries that these things need not be taught!

I stand, despite attacks by uninformed minor educators, for defense of the basic elements of all true education, than which none enter more directly into all phases of the national existence and of the daily lives of every one than do the English language and the sort of mathematics that I have expounded—the only sort that has any right to be called mathematics—the intelligent dealing with the quantities with which the world works. I desire that schools reform, not by banishing study about quantities because it has been poorly done, but rather by improving the teaching regarding these things, and by avoiding misconceptions, such as that which I mentioned concerning the nature of algebra. I demand for our children better—rather than worse—preparation than we have had to face a world in which quantities arise on every hand, in every walk of life, to every active man, to every active woman. Thus, and by no other means, may our sons and daughters build a greater and a safer society in this world of quantitative things!

DR. SIMON FLEXNER

THE PROGRESS OF SCIENCE

DR. FLEXNER AND THE ROCKEFELLER INSTITUTE

In a recent issue of The Scientific Monthly, Dr. Walter J. Meek remarked that "Under the able leadership of Dr. Simon Flexner, the Rockefeller Institute for Medical Research has continually exerted a profound influence on American medical science." It seems appropriate that Dr. Gasser's qualities for guiding the work of the institute should be followed with an account of its development under the able leadership of Dr. Flexner. The story of his achievement as director of the Rockefeller Institute for Medical Research is recorded in its progress from a tentative beginning to a position of world eminence. At the time of his appointment as director, in 1903, the belief was general among doctors that medical discoveries could be made only through the efforts of a few gifted, more or less isolated individuals, working under the conditions in which they happened to find themselves.

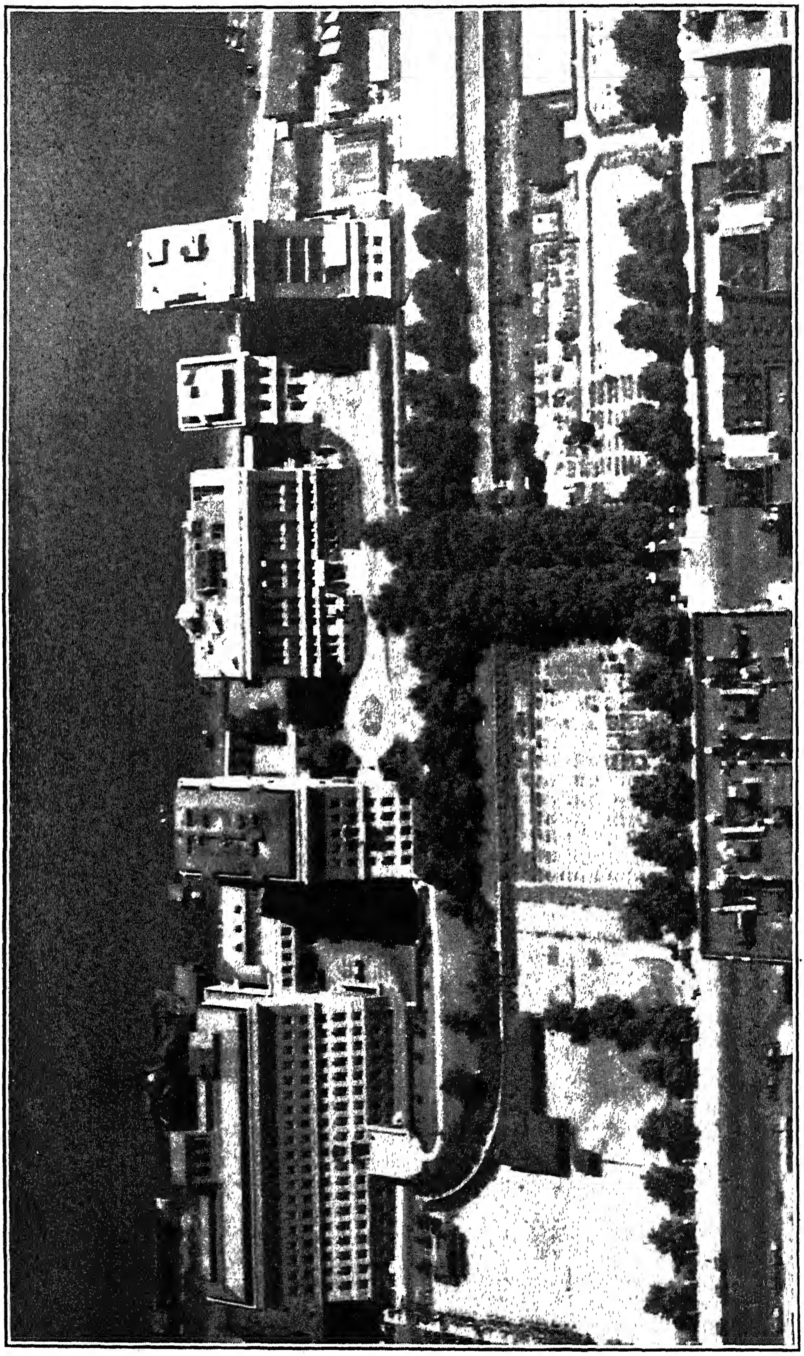
The views of a layman, the late Frederick T. Gates, an associate of John D. Rockefeller, led to the founding of the institute. He became convinced that advances could result from the endowed, purposeful efforts of qualified investigators and he procured Mr. Rockefeller's support for the inauguration of this idea.

The original gift, amounting to $200,000, was not made for the immediate purpose of building an institution for medical research, but was to be used by a group of scientifically trained medical men to ascertain the resources in adequately trained younger men of the universities engaged in the pursuit of medical research. It was to be awarded in grants and fellowships and expended within a period of ten years. During this period, and in this way, it was hoped that more precise knowledge would be obtained concerning the advisability of establishing in the United States an independent institute for medical research. This information was secured more quickly than had been anticipated, so that early in 1902 the conception of a research laboratory to be located in New York City had taken form in the minds of the scientific directors, and met with Mr. Rockefeller's approval.

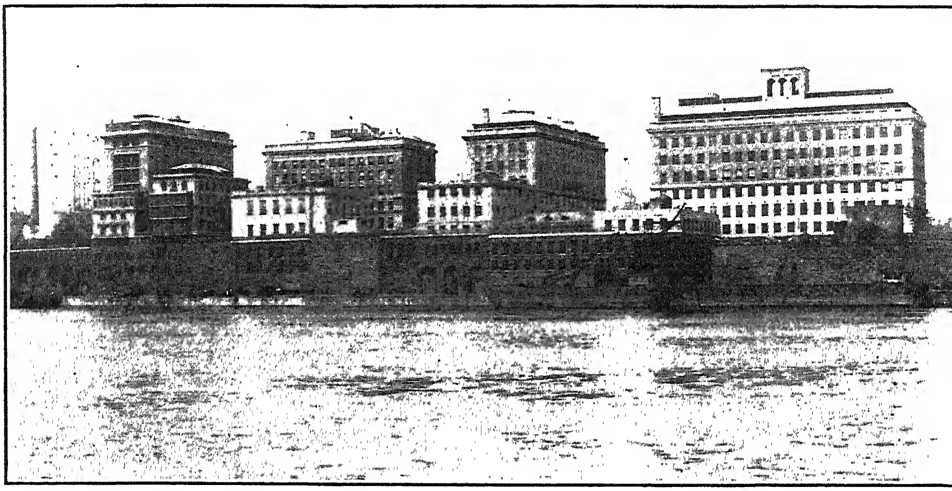
An advisory board of distinguished physicians was assembled, with William H. Welch as chairman, and they invited Dr. Flexner to direct the new enterprise. He was then forty years old, the recently appointed professor of pathology at the University of Pennsylvania and well launched upon an academic career. Nevertheless he accepted, and under his direction investigations were begun on the problems of disease, by a handful of workers in a dwelling house converted into laboratories.

Dr. Flexner had already completed much significant research of his own, at Pennsylvania and the Johns Hopkins Hospital in Baltimore, where he had studied with Dr. Welch. He had taught in both places, had journeyed to the Philippines as member of a commission to investigate diseases there, and he knew the ways of scientists as well as of science. Realizing that genius is always rarer than the material for it to work upon, he saw that the Rockefeller Institute would prove most effective if men were chosen prior to problems. One could trust to opportunity for these.

Among the men he chose were a young Japanese, Hideyo Noguchi, who was later to become a famous bacteriologist and to die of the yellow fever that he sought to understand, and Samuel J. Meltzer, whose singular promise as a



AN AERIAL VIEW OF THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH



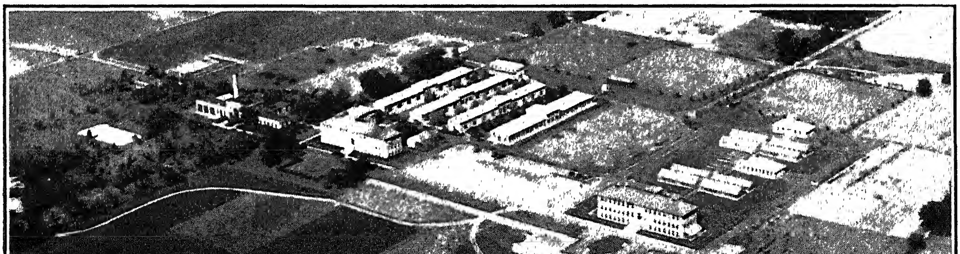
THE ROCKEFELLER INSTITUTE SHOWING THE EAST RIVER IN THE FOREGROUND

physiologist would never have been fulfilled had he not been rescued from the demands of medical practise by an institute appointment.

Dr. Flexner turned his own efforts to the comprehension of cerebro-spinal meningitis, which was then rife in New York City, and he succeeded in developing a serum that much lessened the mortality from the disease and remains the best available remedy for it to this day. He also, under institute auspices, assumed control of the *Journal of Experimental Medicine,* which had suspended publication, and as editor brought it to its present influential position.

The demonstration of the possibilities of the institute resulted in successive gifts to it from Mr. Rockefeller, ensuring it permanence and a widened scope. The first of its several laboratory buildings was erected in 1906, and in 1909 the hospital of the institute, where selected cases of human disease have been treated and investigated by doctors trained for the purpose and free from all other duties.

During this period infantile paralysis had begun to maim many children. Dr. Flexner and the late Paul Lewis succeeded in transmitting the disease in monkeys so that it could be the better studied. This step resulted in findings of signal importance, notably that the virus causing the paralysis enters and leaves the patient by way of the nose and throat. The disease has since been the main subject of Dr. Flexner's personal research, but he has also studied other



LABORATORIES OF THE ROCKEFELLER INSTITUTE AT PRINCETON

infections of the nervous system and the influence of various conditions on experimental epidemics in "mouse villages"—this always with an eye to the human instance.

The fact is recognized now that the solution of some medical problems may require knowledge as broad as the physical world, that the forces determining crystal structure are responsible for the formation of curious spots on the leaves of plants may have importance for human disease. It was not so plain a fact when Dr. Flexner and his associates on the board invited the eminent biologist, Jacques Loeb, to become a member of the institute. Dr. Loeb utilized in his experiments the simplest forms of life for the discovery of general laws.

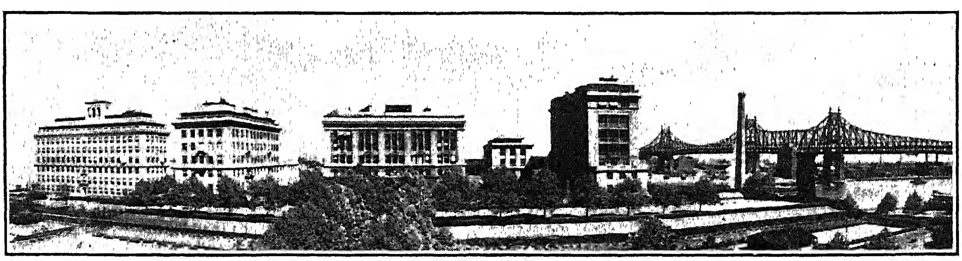
The selection of Theobald Smith to head a division for the study of animal diseases, with buildings and grounds at Princeton, New Jersey, was an equally wise choice. Dr. Smith had been the first to show that insects can transmit disease and to distinguish the differing potentialities for ill of the tubercle bacilli of cattle and human beings. Both these noted investigators added largely to science under the favorable conditions provided for them. Recently a division for the study of plant diseases has been added to that for animals at Princeton.

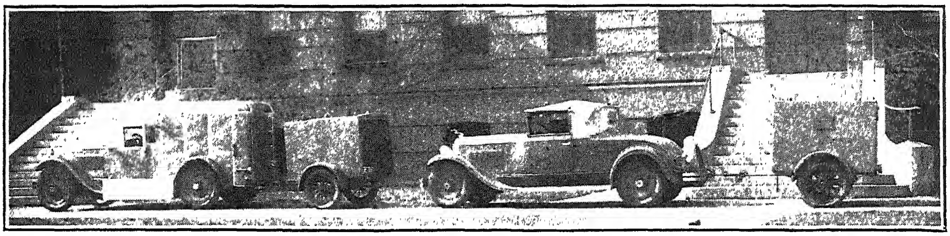
When the institute was first chartered education was set down as one of its purposes. No such organization had existed previously, though groups of workers had assembled about outstanding men, such as Pasteur and Koch, but others have now been patterned upon it. Within its walls many investigators have been trained to research, and many have become influential in research or teaching, here or abroad.

Dr. Flexner's ability as an investigator has found expression not only in his personal work, in his perception of the potentialities of others, but also in administrative steps whereby new opportunities of discovery have been provided. His success in this relation has been evident in the renown of the institute as an instrument for good, over and above the individual merits of any of its workers. Honors have come to him in great variety. He is a member of the Royal Society of London, a Commander of the Legion of Honor of France and has received the Order of the Sacred Treasure of Japan, as well as honorary degrees from numerous universities.

During the world war Dr. Flexner was a colonel in the Medical Corps, and he has served on numerous commissions dealing with public health.

Dr. Flexner plans to devote himself to the writing of a life of Dr. William H. Welch, who was chairman of the Board of Scientific Directors of the institute from the outset until a year before his death in 1934. In spite of his retirement, Dr. Flexner can not but help be the guiding spirit of the institute for many years to come.





THE PORTABLE RADIO APPARATUS AT HARVARD UNIVERSITY

The Cruft Laboratory of Harvard University has recently constructed an experimental car to be used in a variety of new radio investigations. Experimental trucks have often been used by broadcasting companies, radio inspectors, police departments and other agencies interested in some special type of engineering application. Ordinarily these trucks have been employed in making surveys of field strength produced by a definite transmitting station, or in relaying special broadcasts to a control station.

The new portable laboratory differs from these previous experimental trucks in purpose and in construction. It is designed to carry on in the field a wide variety of scientific measurements which have hitherto required the facilities of fixed stations and to undertake new types of experiments which could not be performed in ordinary laboratory buildings.

The new developments are based on experience previously obtained by the Cruft Laboratory staff in less extensive field measurements, involving the use of two automobile trailers. More than a year ago echoes of radio signals were recorded automatically on photographic paper at points many miles distant from Harvard University and were compared with echoes received in Cambridge, close to the transmitting station. In this way it was possible to obtain an indication of the movement of individual clouds of electrons, drifting over the earth at a height of approximately 62 miles. The echoes appeared and disappeared several minutes earlier at one station than at the other. The new portable laboratory carries transmitting sets as well as sensitive receiving equipment, and it is now possible to extend the scope and the accuracy of the simultaneous experiments.

The transmitting set is a special type that sends a circularly polarized or "corkscrew" wave, which can be made to spin in a clockwise or counterclockwise direction as it moves through space. The set can also transmit the ordinary type of radio wave. Voice and code modulation are provided for communication with the home laboratory and with other cooperating stations. Two battery-operated high-voltage generators and an alternating-current generator provide full power for all apparatus even when the mobile laboratory is completely isolated, though outside power sources may be substituted when available. A wide choice of wave-lengths is provided.

In certain types of long-distance simultaneous echo experiments a trailer is also used. In this case elaborate crystal-controlled vacuum tube circuits permit extremely accurate synchronization of the receiving apparatus with the transmitter at the home laboratory. This synchronization is accurate to 0.0001 per cent. per hour and is independent of the radio wave and the characteristics of the power line.

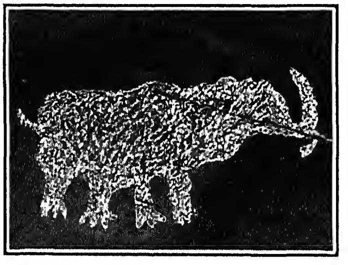
The laboratory carries an ultra-high-frequency transmitter, and three associated receivers operating on 5 meters, 2.5 meters, 1.25 meters and on special experimental assignments. These are used in studying the effect of geographical and meteorological conditions.

H. R. Mimno

Department of Physics,
Harvard University

THE MOAB MASTODON PICTOGRAPH

Rock carvings, variously known as pictographs or petroglyphs, are familiar features to persons who have worked in the canyon-cut country of the Southwest. That they have not excited greater interest is perhaps due to the fact that they commonly portray such things as aboriginal man was doubtless familiar with; goats, serpents, human figures and fowls make up most of those I have personally examined. In 1924, however, I was informed by John Bristol, of Moab, Utah, that there was what he believed to be a mastodon pictograph some three miles down the Colorado Canyon from that village. Though this excited my interest, the search had to wait for ten years until I was again in that vicinity last summer. In August of last year, Dennis Baldwin, Fred Strong, Jr., and I, after considerable searching, found the desired pictograph.



That this carving is designed to be an elephant or mastodon is evident. It represents a good deal of work on the part of the primitive artist, for the figure, from the end of his very "pachydermous" tail to the tip of his trunk, is almost two feet long and appears to have been made by a painstaking method of chipping the whole figure from the solid rock wall with a blunt pick, chisel or similar tool. It is a recessed or etched figure, composed of closely spaced "pock marks."

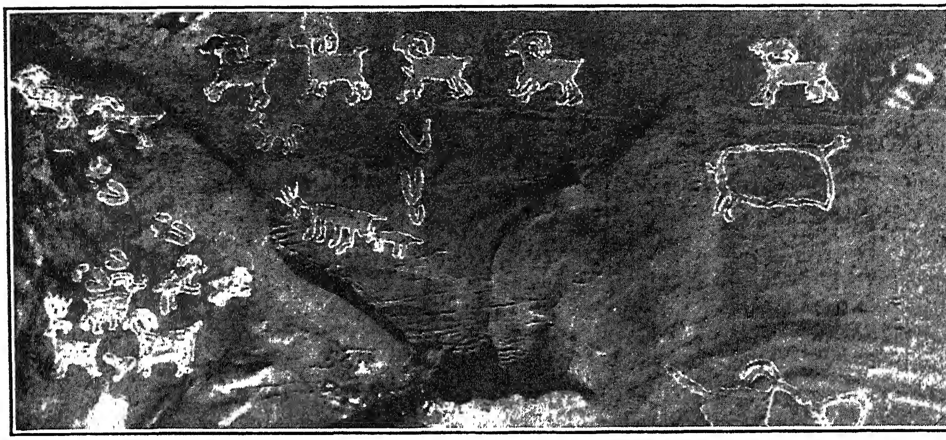
Such figures do not stand out in sharp contrast against their dull red sandstone walls, and one might pass within a few feet of even so large a one as this, time after time, without seeing it. Chalk was carefully rubbed over the pitted surface in order to make photographs.

That this pictograph is genuine seems entirely plausible to me, else the hundreds of similarly etched figures of goats and other creatures are not.

In the first place, the technique of the various pictographs which I examined show a decided uniformity of method of execution; all the larger figures have been chipped from the rock walls with some blunt pick or awl-like tool.

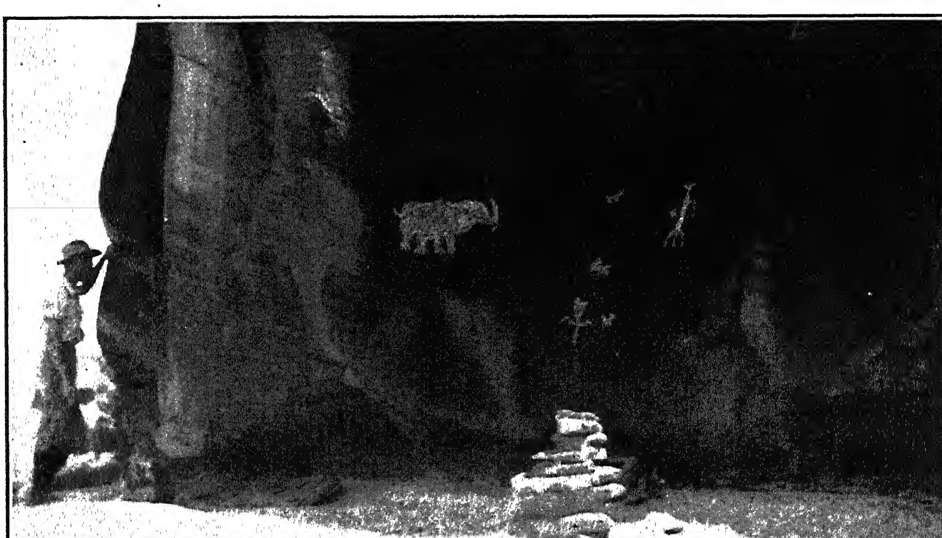
In the second place our "mastodon" occupies an inconspicuous place; it is back from the river about two hundred yards and well above a rugged rock ledge at least fifty feet high. Men might pass it by, as they appear to have done, for years without seeing it, for it is not near any path or route which any one would normally take in going up or down the river. Were it the work of some itinerant cowboy or other person wishing to establish a hoax it does not seem that he would have deliberately placed the figure in a position where the likelihood of its discovery would be so remote. Nor does it seem any more reasonable that an insincere artist or worker would devote so much time and energy to such a project, as is necessarily involved in the execution of this figure.

Thirdly, a curious kind of "vandalism" has prompted many persons to scratch their initials and even stupid inscriptions across some of the more accessible and better-known pictographs. I saw one set of initials bearing the date of 1896 beside some goat pictographs. The latter lacked the freshness of the initials, indicating that they are probably not recent in the sense that the initials are. It would be pure folly,

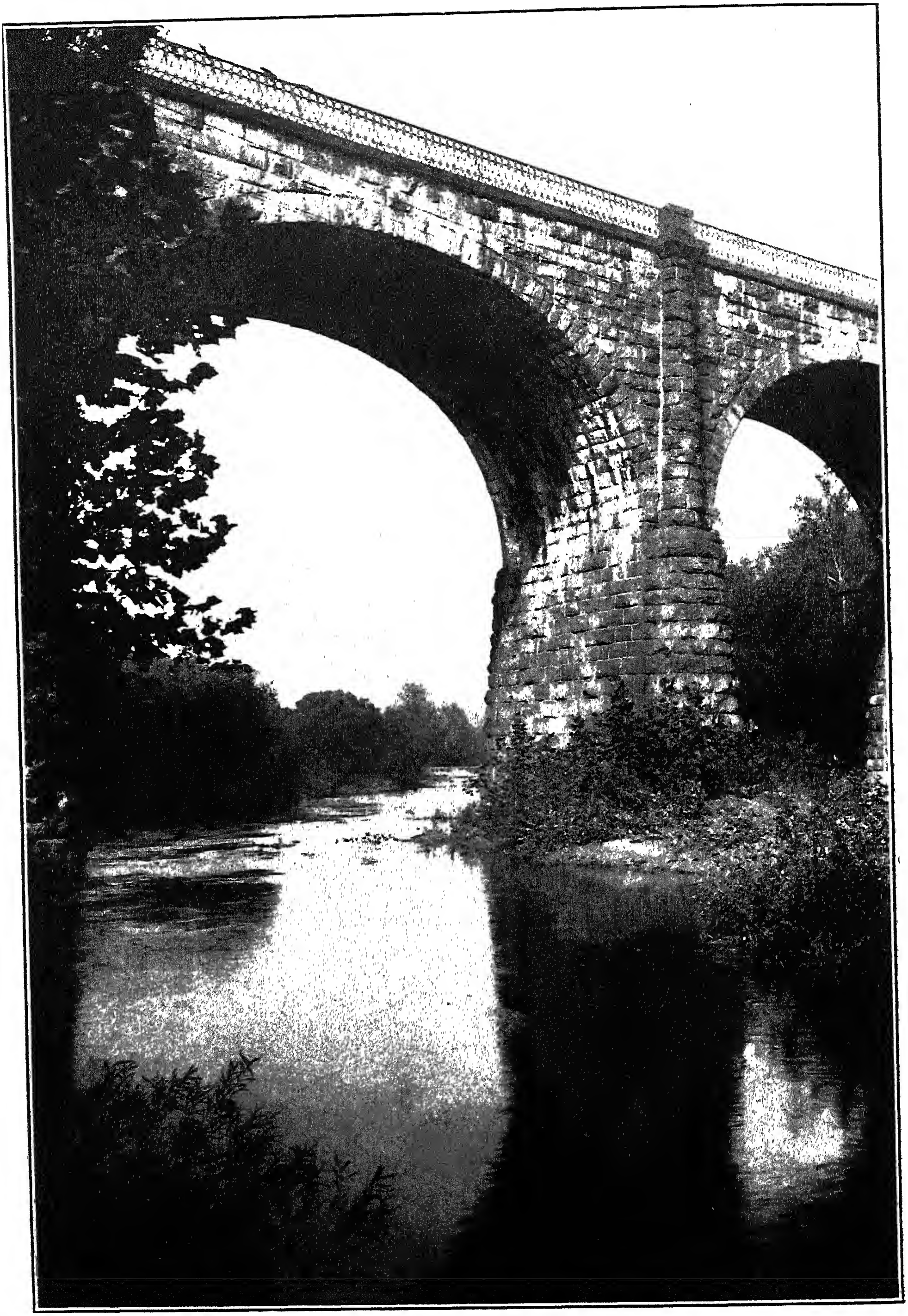


SOME COMMON KINDS OF PICTOGRAPHS

however, to hazard a guess as to their actual age, for it would be most difficult to estimate the rate of weathering of such rock carvings in the partially protected places they occupy on the canyon walls. There does not, however, seem to be any good reason for supposing that such figures as the one here described possess any special antiquity. Its chief interest lies not in its actual age, but in the fact that it appears to be an authentic link between aboriginal man and the elephant or mastodon, for it is highly improbable that any primitive artist could have achieved so good a likeness without having seen such a creature or having at least seen a picture of one done by some fellow artist.



THE MASTODON PICTOGRAPH



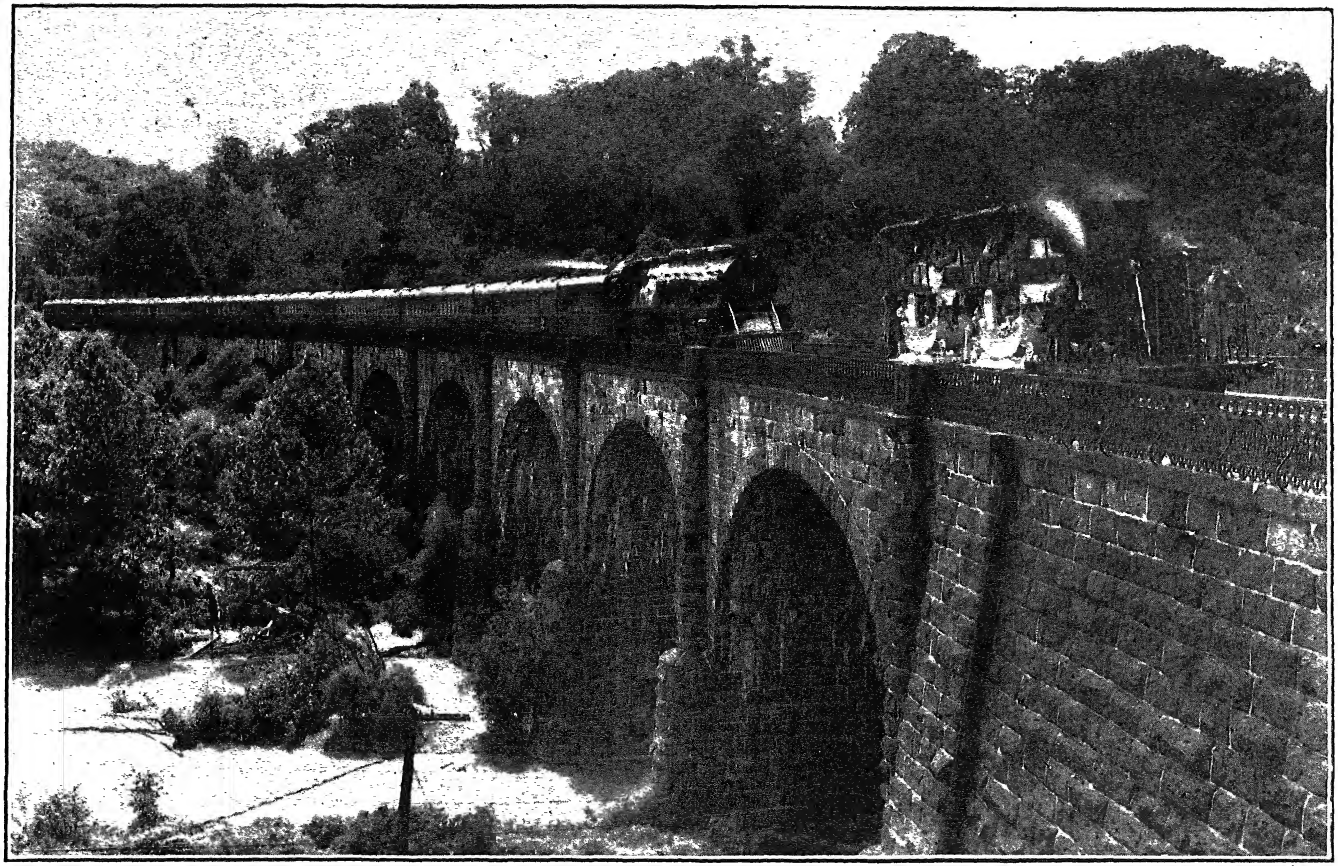
THE OLDEST STONE-ARCH RAILROAD BRIDGE IN THE WORLD: THE THOMAS VIADUCT ACROSS THE PATAPSCO RIVER

On July 4, 1835, a railroad president and his group of directors watched a little "grasshopper" locomotive steam its way across a new stone bridge. That bridge was the Thomas Viaduct. It spanned the Patapsco River between Relay and Elk Ridge Landing, Maryland, and this was its dedication day; after one hundred years, this viaduct seems destined forever to remain the faithful servant of the railroad. Trains of all sizes and weights have stood still upon it, crawled over it and flashed across it, but never a stone falls, never an arch quakes. The railroad was the Baltimore and Ohio, America's first, and Philip Thomas, its first president. Soon the last shipment of rail iron would arrive from England and then the first railroad would nose its way into the heart of the nation's capital. The weightiest problem of the building of the Baltimore-Washington branch of the railroad had been solved.

For five years the railroad had been carrying passengers and freight on the "Old Main Line" between Baltimore and Ellicott's Mills *via* Relay, the halfway station. Relays of horses were stationed here to provide fresh "motive power" for the railroad in its earliest days. Hence the name. Here, too, the railroad had to veer to the west—for the Patapsco stopped its course south toward Washington. It was near here that Peter Cooper in the summer of 1830 had driven his little Tom Thumb locomotive in the famous race with the coach horse. He lost the race, but settled for all time the practicability of steam as motive power for railroad trains. For four years now steam engines had been hauling the trains. The "York," the first practical locomotive, had been followed by the "Atlantic," "Arabian," "Traveller" and several lesser lights. And now there were four new ones—all of the same old "grasshopper" type with vertical boilers, and named for the first four presidents of the United States. These were all set to steam into Washington. The line now was open as far as Bladensburg. Orders had been issued, and within a few days service on the Washington Branch would begin, with stage coaches meeting the trains at Bladensburg and completing the journey to the city.

Designed by Benjamin H. Latrobe, Baltimore architect, the building of the Thomas Viaduct was executed by John McCartney, of Ohio, under the direction of Jonathan Knight, principal assistant engineer of the railroad, and Caspar W. Wever, superintendent of construction. The material was native granite. In the 1840's the viaduct was found to stand up well under a locomotive pulling thirty loaded freight cars—a total weight of 113 tons. A century later we find the same viaduct—with no change in its construction since it was built—bearing with ease the heaviest engines, some weighing upwards of 350 tons. Engineers estimate that it will be able to bear the weight of heavy trains for hundreds of years to come.

The span consists of eight elliptical arches, constructed of native granite, with clear openings that vary in length from 57 feet 10½ inches to 58 feet 4½ inches. Its total length is 612 feet; height, 60 feet; width, 26 feet. It is built on a four-degree curve. The depth of its foundation is not known. Its pier sides are on radial lines, forming arches. Each pier is 9 feet by 26 feet. The structure contains 24,476 cubic yards of



THE OLDEST STONE-ARCH RAILROAD VIADUCT IN THE WORLD

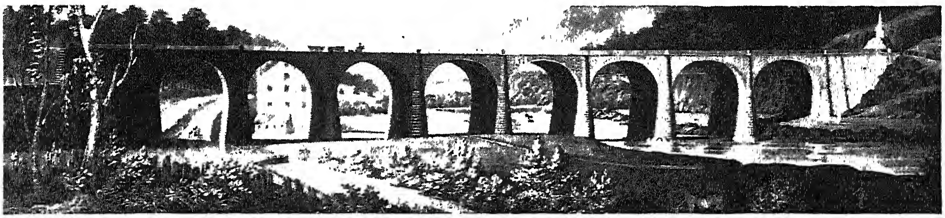
THIS BRIDGE COMPLETED ITS FIRST CENTURY OF CONSTANT USE IN JULY WITHOUT CHANGING A STONE. THE 103-YEAR-OLD ATLANTIC LOCOMOTIVE AND IMLAY COACHES IN VOGUE IN THE 1830'S ARE CONTRASTED WITH THE NEW STREAMLINED TRAIN—THE ROYAL BLUE—THAT BEGAN USING THE BRIDGE EARLY IN THE SUMMER ON THE WASHINGTON-NEW YORK ROUTE.

masonry and cost $142,236.51, or $5.80 per cubic yard of masonry. It would be difficult to duplicate the structure to-day, since there are no longer any stone-masons who do that sort of work; and even if there were, it could not be duplicated for less than a million dollars. The original structure was made wide enough to accommodate double tracks. It is the oldest stone-arch railroad viaduct in the world.

When the last stone had been placed and the finishing touches added, McCartney, wishing to perpetuate his own name in connection with this masterpiece of construction, erected at his own expense a monument, which is shown to the right in the reproduction of the drawing on stone. On it he had inscribed the names of the directors of the railroad, the directors of the state of Maryland and those of the city of Baltimore, the names of the architect and others connected with the building of the viaduct, and his own name, "John McCartney of Ohio," in two places.

On August 25, 1835, the first official run was made by trains from Baltimore, across the viaduct and into the heart of Washington. The curve of the viaduct made it possible for passengers to view portions of it and to comment upon it as the trains crossed it. One writer of the day called it "one of the noblest bridges ever spanned." Another termed it a "most beautiful work of art." Still another declared that he wept tears of joy at the thought of living in an age that presented such a magnificent view. At that time it was the largest stone bridge in the country. Until after the Civil War this was the only railroad into Washington, and over this viaduct passed all the troops and supplies of the Federal Army. The span was heavily guarded.

The old Relay House, located in a charming spot on the east bank of the river, was a famous old hostelry. During the days of early railroading all trains stopped here to changes horses. Later they changed cars—not because this was necessary from an operating standpoint, but because it was thought it would be nice to have passengers continue their journey in a fresh, clean coach. Relay House was for years an eating place for train passengers. When the new Relay House was built, in the seventies, the main building, like its predecessor, was made as a hotel and passenger station in one. It became widely known as a summer resort and was visited by several presidents of the United States. M. T. S.



THE THOMAS VIADUCT

A DRAWING ON STONE BY THOMAS CAMPBELL, DATED JULY, 1855.

GASOLINE FROM COAL

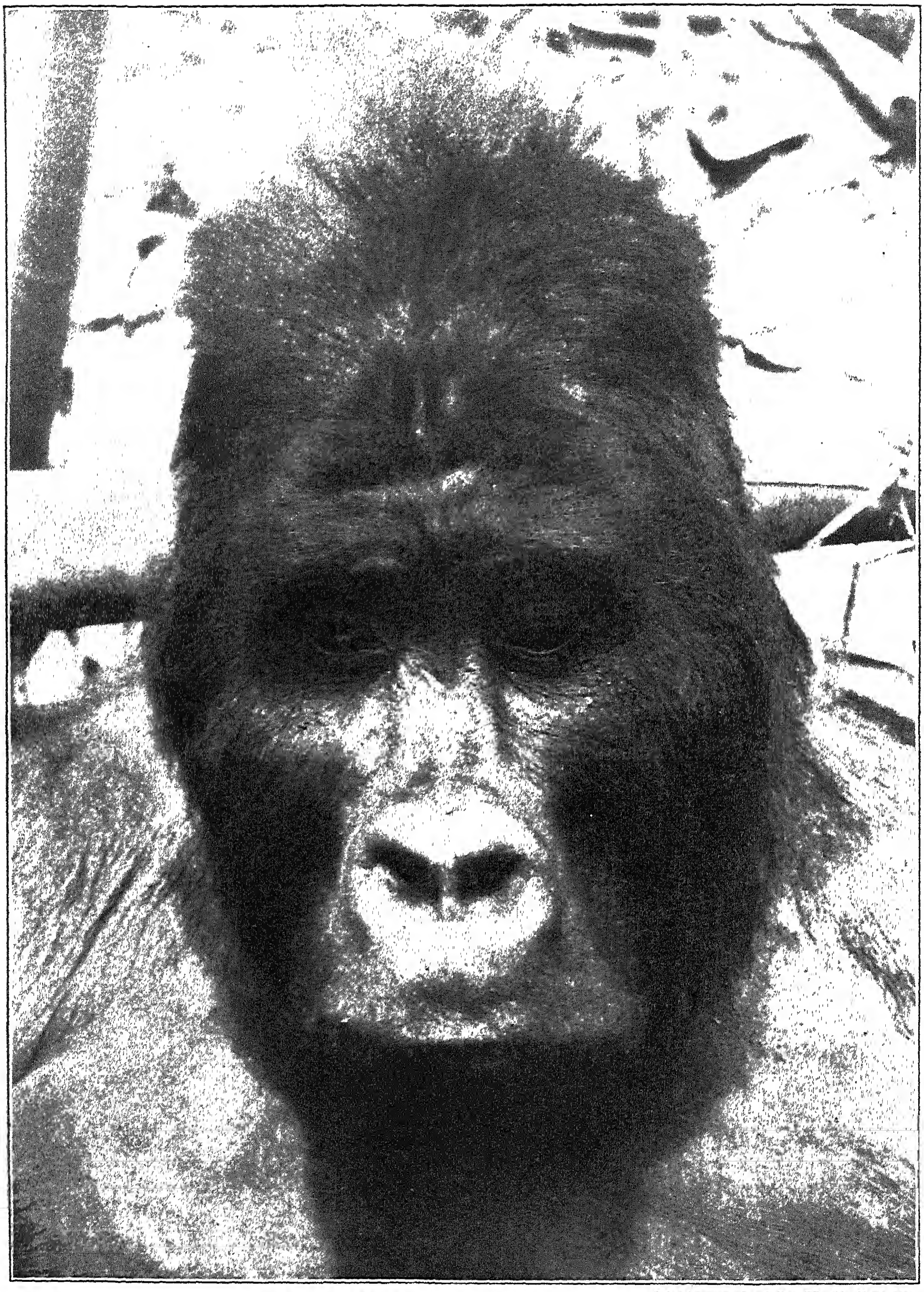
THE famous German I. G. chemical works of Oppau-Ludwigshafen have completed a three months' trial run with a continuous process for making gasoline from coal, according to Science Service. A thousand kilos (450 pounds) of coal yielded 600 kilos (270 pounds) of gasoline of good anti-knock quality. Using the Bergius process of hydrogenation, powdered coal and heavy oil are mixed in a chamber with catalysts under a pressure of three hundred atmospheres and 460 degrees centigrade temperature.

Pressed by the lack of petroleum products within its boundaries and the lack of colonies which might produce petroleum, Germany for years has continued gasoline-from-coal research. The present trial run is one of the largest ever completed. And Great Britain, just across the North Sea, has gone into the field, not because its colonies do not yield oil for gasoline, but to encourage the industry in event of war. The British Navy buys large amounts of British gasoline made from coal and low-grade oils at high prices to subsidize the industry and keep it going.

Gasoline from coal and low-grade oils is technically possible but hardly profitable in America. It costs at least three times as much at the factory for a gallon of coal-made gasoline as for a gallon of the current American gasoline now on sale here. With the warning of the U. S. Geological Survey that present petroleum reserves, if used at present rates, will last only another thirteen years, government scientists suggest, at every opportunity, that the United States should enter into a study of coal gasoline. The U. S. Bureau of Mines, while not doing this tyye of research at present, has the problem near the top of its list and will undertake investigations when very modest funds are appropriated.

From the American standpoint the main problem still to be solved is the optimum conditions for using American coals, which differ decidedly from European coals. Already American oil companies have devised processes whereby low grade petroleum can be turned into superior gasoline. The next step would be to use the tarry products from petroleum distillations for the same purpose. And finally would come the use of coal dust itself.

While America has not the immediate economic pressure for starting coal dust gasoline research, a decade hence the situation will be different. Government scientists, foreseeing this day, are anxious to get at the preliminary work so that when the time comes they can present a whole program to relieve the problem. At present what work has been done in the United States has been mainly in university laboratories, so much so in fact that the problem is principally of academic interest.



Photographed by H. C. Raven

THE DEAN OF THE ANTHROPOIDS

HEAD OF *Gorilla beringei*, MALE; SHOT BY DR. H. C. RAVEN AT TSCHIBINDA IN THE MOUNTAINS WEST OF LAKE KIVU.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1935

IN QUEST OF GORILLAS[1]

I. ON OUR WAY TO GORILLA-LAND

By Dr. WILLIAM KING GREGORY

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY; PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

At the College of Physicians and Surgeons of Columbia University Professor Dudley J. Morton has long been studying the queer and often sad results of our being made-over quadrupeds. After countless ages of quadrupedal life our ancestors somehow learned to walk on their hind legs; but in so doing they necessarily concentrated their entire weight upon their hind feet. To this added burden even our own feet have not yet become perfectly adapted, as shown by their frequent breakdown. In addition to this we have forced our feet into cages, called shoes, which at best have deprived us of the leathery soles of our ancestors and at worst have transformed our feet into horrible monstrosities. Professor Morton, from his studies of orthopedic problems, found that a great deal of both theoretical and practical value could be learned about the mechanism of the human foot by viewing it in the light of its long evolutionary history. It had been shown by others that nature in the feet of many animals still living has preserved various stages illustrating the transformation of a quadrupedal, ground-dwelling type of foot first into the more or less hand-like feet of the monkeys and apes and finally into the peculiarly modified foot of man. It remained for Professor Morton, however, to make successful application of such past evolutionary data to the interpretation of the mechanism of the present evolutionary stage of the foot in the American variety of *Homo sapiens*. For further progress in this work he needed to study the anatomy of the feet of ordinary mammals, of monkeys, gibbons, chimpanzees, orangs, gorillas, as well as of primitive human feet, unspoiled by the wearing of shoes. Thus when he turned to us in the Department of Comparative Anatomy of the American Museum of Natural History for material, we could give him almost everything that he wanted for dissection, with the important exception of adult gorillas and primitive unshod humans. But in this department our associate curator, Henry C. Raven, was well fitted by long experience and training in field and laboratory to go after the material that was needed.

So, to make a very long story short, Professor Morton and his colleagues at the Medical Center secured the personal and official backing of President Butler, who in turn brought it about that Columbia University provided the funds, while the American Museum of Natural History supplied the leader of the expedition, which was thus sent to tropical

[1] The story of an expedition sent by Columbia University and The American Museum of Natural History to the Belgian Congo and the French Cameroon, Africa, in 1929 and 1930.

Africa under the joint auspices of the university and the museum.

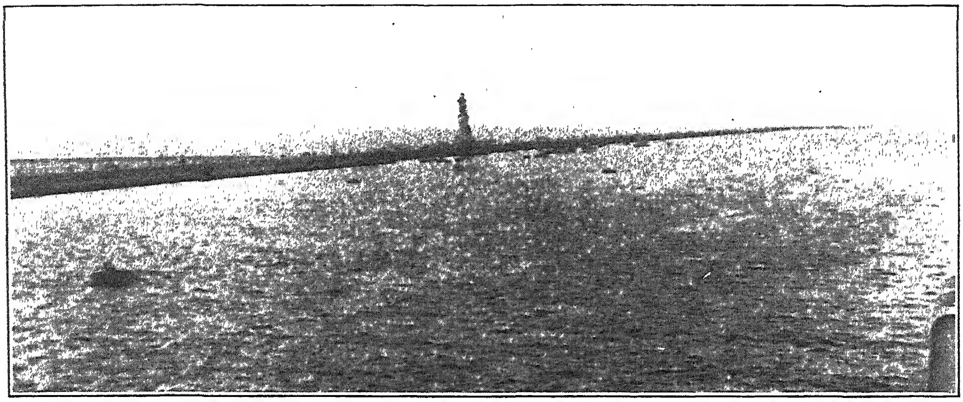
As my three colleagues will be so often mentioned in the following pages, it may be well to begin with a brief characterization of each of them, even at the risk of incurring their modest expostulations and perhaps reprisals when their individual stories of the expedition come to be written.

Mr. Raven, the leader of the expedition, is well known among museum circles for his extensive zoological explorations and collections in Borneo, Celebes, Australia, Greenland and Africa. His field studies on the natural history of many mammals have been happily supplemented by his sound anatomical investigations in the laboratory. He is a rather calm and deliberate person, one who answers questions only after a certain pause, which might sometimes irritate persons of the Gallic temperament. "*Festina lente*" and "Don't shoot till you see the whites of their eyes" might well be his favorite maxims. "It's dogged as does it" might also be appropriate. In the forest he is remarkably sure where he is, no matter how many twists and turns the quarry may have made, and when the critical moment comes he is uncommonly quick on the trigger. He delights in mastering the cussedness of inanimate objects, such as refractory mechanisms, and loves carpentry, cabinet-making and the sailing of cranky boats. Native technique, as of making houses and devising traps and snares, appeals strongly to him and he can live on locusts and wild honey if necessary. He finds that, as a rule, Dyak head-hunters, Malay pirates, Eskimo seal hunters, Australian trackers and African ex-cannibals have learned many valuable ways of adapting their environment to their needs and no false sense of superiority prevents him from learning from them. Upon him fell the major responsibility of laying out the route of the expedition, obtaining reliable estimates of cost, purchasing the field equipment and getting the gorillas.

The senior naturalist of the expedition was Professor J. H. McGregor. Among the main assets of the expedition was his more than encyclopedic and practical knowledge of zoology, embryology, anatomy and photography. Scarcely less important in sustaining our morale were his instantaneous and witty retorts and his extensive and delectable stock of Scotch and other stories. "Happiness in every box" might have been his motto, and many were the amusements, tricks and presents which he contrived to bestow upon the jolly black children that played around our camps in tropical Africa.

Dr. Earl T. Engle, associate professor of anatomy at Columbia University, the third member of our expedition, is a big athletic blond with a broad smile and a friendly way with dogs and humans. He is quick, incisive, accurate, original and dynamic. On our long journey across Africa the only thing that really peeved him was enforced idleness, during our many seemingly interminable waits for porters, customs officials, camions, trains, steamboats, etc. He was especially interested not only in comparative anatomy and zoology, but in the medical equipment of the Belgian Congo and was active in securing observations, photographs, footprints, etc., and records of African natives.

The main reason why I too was a member of this expedition was that I had firmly taken it for granted that I was going to be, and fortunately it did not occur to any one to question it. At the Museum of Natural History we had had some lively discussions on the origin of man, Professor Osborn stressing man's immensely ancient lineage and his alleged freedom from the taint of the "bar sinister of ape ancestry," while I had defended the right of the chimpanzee and the gorilla to be recognized as our poor relations and as mute witnesses of



Photograph by H. C. Raven

THE PATHWAY TO AFRICA

BREAKWATER AT PORT SAID, LEADING TO SUEZ CANAL; STATUE OF DE LESSEPS AT THE FAR END.

our former low estate. I had published various papers, chiefly based on the study of the skulls, teeth and skeletons of fossil and living members of the order of Primates, but I was keen to see for myself how man's nearest living relatives lived in their native forests and to acquire some first-hand knowledge of the teeming life of present and past ages in Africa. I was also especially interested in the evolution of fishes and hoped to see some of the most famous African species in their own environment.

Thus we four, shortly before midnight on May 29, 1929, found ourselves in the smoking-room of the *Aquitania,* bound for London *en route* for Dar-es-Salaam on the east coast of Africa. Africa, however, was still a long way off and our immediate anxiety was to obtain permits from the Belgian authorities to shoot one or more adult male and female specimens of the mountain gorilla, which lives in the mountains and highlands east of the Congo River, and then to obtain permission from the French authorities to secure an equal number of the lowland species from the region north of the Gaboon in western Africa. No anatomical laboratory in the world, so far as we knew, had adequate material of either species of gorilla. A few young specimens from zoological parks had been dissected, but the adult anatomy was but poorly known.

Soon after arriving in London we went to pay our respects to His Excellency, M. Émile de Marchienne, Baron de Cartier, who was then the Belgian ambassador to the Court of Saint James but who had formerly been the Belgian ambassador to Washington. The baron had encouraged and aided the late Carl Akeley, of the American Museum of Natural History, whose report to King Albert had assisted the latter in his plan to establish the Parc National Albert in the mountains of the Belgian Congo, as a perpetual sanctuary for the gorillas and other wild life there. Baron de Cartier explained to us that from his friendship and close association with Carl Akeley he had acquired Akeley's determination to save the gorilla from extinction. He had, in fact, become an ardent conservationist to the point of being unwilling to allow a single gorilla to be killed even for scientific purposes. He well understood the value of studies on the anatomy of the gorilla, but if we were allowed to take two specimens, or even one, would not our scientific reports lead other specialists to question our conclusions, at least at certain points, and would not they then clamor for more sacrifices? This was a home-thrust that

we had not expected and with sinking hearts we replied that we were not, of course, requesting any violation of the sanctuary of the Parc National Albert; we were asking for permission to obtain one or two gorillas somewhere else in the vast territory of the Belgian Congo. We said also that great numbers of gorilla skins and skulls had been taken because it was far easier to do this than to preserve every bit of the precious body for anatomical study; but that it was our object to secure this priceless anatomical data before all the gorillas outside the Parc National should be destroyed by natives and white settlers. The baron insisted that it was the intention of King Albert's government to enforce the laws for the protection of the gorillas. At last, however, he consented to give us letters of introduction so that we could explain our mission to the proper authorities in Brussels.

While in London, Brussels and Paris we were extremely busy in completing our equipment, obtaining letters of introduction, maps, information about routes, etc., but I, who had less of this business than the others, had time to make notes in the several universities and museums of natural history. All these places contained a wealth of material bearing on our special interests, the comparative anatomy and evolution of vertebrate animals, including man. For example, at the British Museum (Natural History) in London I again examined the fossil jaw and teeth of *Dryopithecus fontani,* an extinct ape from the Miocene epoch of Spain, described by Sir Arthur Smith Woodward. This highly interesting form was rather closely related to the ancestors of the gorilla and, together with other similar material from France, Germany, Austria and India, it proves that the existing gorillas, chimpanzees and orangs are merely the widely scattered relicts of an older anthropoid group which was formerly very widespread over the semi-tropical zone of the Eastern Hemisphere. In this same *Dryopithecus* jaw each lower molar tooth has three principal cusps on the outer side and two on the inner side, exactly the same number as in the lower molars of primitive races of men. Moreover, the bases of the cusps are separated from each other by a definite system of grooves, each of which clearly corresponds to a similarly placed groove in primitive human molars. These and hundreds of other striking resemblances between man and the anthropoid apes can hardly be explained away as coincidences or accidental resemblances. There is, in fact, a pervasive resemblance between the entire anatomy of man and that of the gorilla and the chimpanzee, accompanied by many differences; the latter have presumably been acquired after the separation of man from the basal anthropoid stock.

At University College, London, Professor J. P. Hill showed us some of his beautiful microscopic sections of the wall of the uterus and of the membranes connecting the young with the mother in the lemurs, the tarsier, South American monkeys, Old World monkeys, apes and man. He has shown that the foetal membranes of man are almost identical with those of the gorilla and the chimpanzee. Thus the leading English authorities all support the view held by Sir Arthur Keith, Sir Grafton Elliot Smith, Professor Adolph Schultz, of Johns Hopkins University, and others, including myself, that the ancestry of man merges with that of the anthropoids before descending to lower levels of the family tree of the primates.

At the Royal College of Surgeons we had the privilege of examining some of the beautiful anatomical preparations upon which Sir Arthur Keith based his presidential address before the British Association meeting in 1928 on "The Origin and Evolution of Man." No better statement of the present status of the problem of man's relationships to the

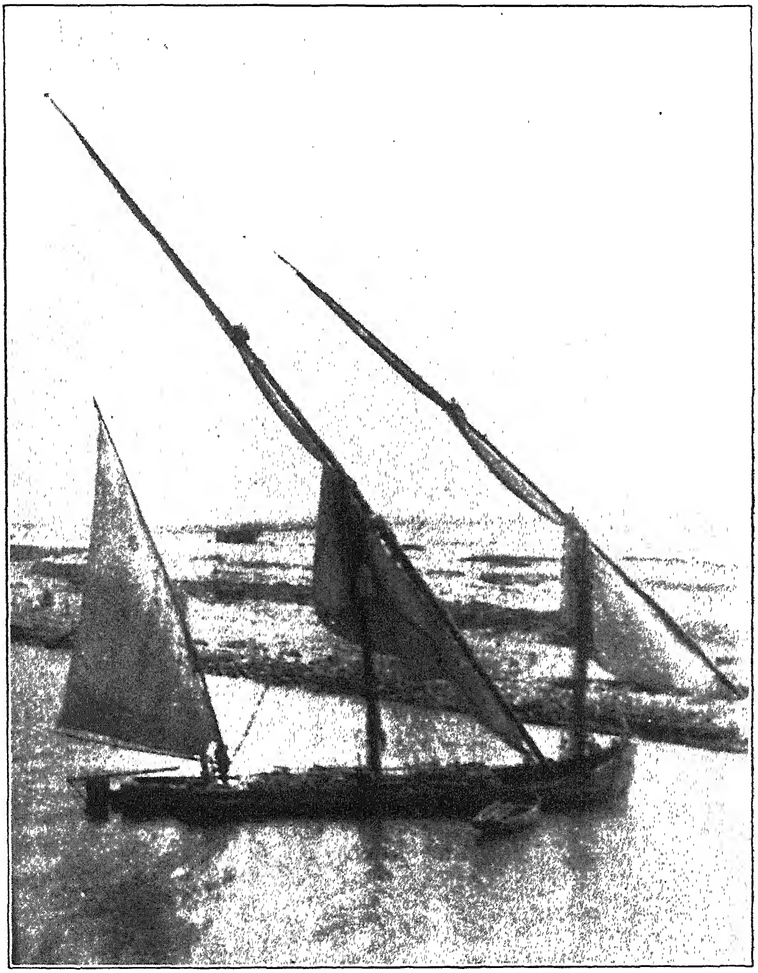
existing anthropoids could be recommended to the general reader.

At the home of Miss Alyse Cunningham in London we had the pleasure of hearing about her adventures on the west coast of Africa, where she and her nephew, Captain Penny, had obtained a pigmy hippopotamus and a baby gorilla. Some of the conditions she had encountered—swarms of mosquitoes, biting bugs, venomous centipedes, burning days and steaming nights—did not sound very alluring to the prospective explorers.

At the Zoological Gardens in London we found a splendid collection of primates, including chimpanzees and orang-utans, all in excellent condition. Their deserved popularity with the crowds confirmed us in thinking that our own humble efforts to teach the "Darwinian theory" of man's origin were far surpassed by the unconscious teaching of the apes themselves, whose all too human antics were heartily applauded.

At this spot I heard a little old woman say very firmly to her friend, as they both gazed at a large chimpanzee, "Oh, *we're* not re-*li*ted to 'im"; as if to deny any claim that " 'E's relited to us."

At the beautiful Aquarium near-by we



Photograph by H. C. Raven

PHARAOH'S SAILS

had the privilege of seeing living specimens of some of the most famous African fishes, in whose anatomy and evolutionary history we had long been interested. Here were many "living fossils" surviving from earlier ages of the earth's history, along with the very latest modes in body-form and decorations in the swarming African fish world.

When we arrived in Brussels we were met at the station by Dr. J. M. Derscheid, the secretary of the Belgian "Office for the Protection of Nature." This is a remarkably efficient and compact organization for the encouragement of national and international movements for the protection of the fauna and flora in all countries of the world. This office keeps up to date a complete file and transcript of all laws dealing with the protection of game or other natural resources and it sends accurate information on such matters to those engaged in the struggle for the conservation of wild life. Dr. Derscheid was especially interested in the protection of the gorilla, for he had been Akeley's companion in the field and had himself made a close-up study and census of the gorilla population of the Parc National Albert. But, a zoologist himself, he also knew the need for well-preserved material for the study of the anatomy of the adult gorilla. Accordingly he gave his personal endorsement to our request to obtain two adult specimens in the Belgian Congo; he introduced us to various high officials of the government, entertained us handsomely at his own residence and gave us maps and much information of great value. Thus was continued a long record of friendship and generosity to the American Museum of Natural History on the part of the Belgian government and its officials, who had at various times made it possible for Lang and Chapin, Akeley, Clark and others to secure splendid collections for the museum from the Belgian Congo.

At the Museum of the Belgian Congo at Tervueren, a suburb of Brussels, we saw fine examples of the native sculpture, together with mounted groups representing different phases of the life of the people. Of even greater interest to me was the large relief map showing the topography and geology of the Belgian Congo. From this I made notes which were useful later when we were traveling across Africa.

In Paris the *Musée d'Histoire naturelle* was my special mecca, as it contains priceless material illustrating the history of life on the earth. There I examined two other jaws of the fossil ape *Dryopithecus,* which, as already noted, appears to stand in or near the line of ancestry of the gorilla, chimpanzee and man. Seven months later, on my return to Paris, the eminent curator of the fossil collections, Professor Marcellin Boule, showed me among other treasures the foot of a fossil man of the Neanderthal species, which has the great toe markedly divergent, recalling to some extent the condition in the gorilla and the chimpanzee.

At the *Jardin des Plantes* we stood in front of the house where the illustrious Lamarck had lived—he who almost a century before Darwin boldly proclaimed that proud man was essentially a tailless ape that had acquired a large brain and learned to walk upright!

In the menagerie near-by we found a very engaging family of orang-utans. The mother orang conceived the bright idea of putting an empty pan on top of her head and was so much pleased with herself that she laughed visibly, though not audibly except for a sort of panting and hissing sound. A very young gorilla in the same collection was an insane-looking creature who illustrated some of the worst possible results of keeping a young gorilla in a cage without companions or playthings.

In Paris we encountered quite unexpected and dangerous opposition to our request for permission to secure gorillas

from the French Congo. Certain officials had taken offense at what they considered to be the unwarranted interference of the New York Zoological Society in protesting against the selling of baby gorillas by animal dealers. Nevertheless, largely through the kind endorsement of our French and Belgian scientific colleagues, our request was finally forwarded to M. Antonetti, governor-general of the French Congo, who many months later received us with great courtesy and gave us letters of introduction to M. Marchand, governor of the French Cameroon, where Mr. Raven finally secured the desired specimens of the West African gorilla.

At last all our preparations were complete and it was with no little relief that we boarded the night express from Paris to Marseilles. At Marseilles we paid a visit to the *Musée Longchamps,* a fine building at the top of a steep hill; in front of it is a great semicircular stone structure with long flights of steps, fountains, huge arches and abundant sculpture. But this imperial-looking monument stands in wide contrast to the more or less neglected museum at the summit. In its deserted halls interminable rows of ancient stuffed animals and hundreds of jars of alcoholic fishes (some of them very rare and famous species which we had never before seen) stand as evidence of the diligence and enthusiasm of the founder and his immediate successors. But now there are no signs of life about the museum, through which we were shown by an elderly porter who let us in through the basement. The zoological park near the museum was hot and dusty and very few visitors were present. Apparently there is not much popular interest in natural history in Marseilles at the present time.

On June twentieth we went down to the wharf, climbed up the black side of the steamer *Chambord* and began to feel that at last we were really on our way to Africa. All our numerous boxes, bedrolls and other camp equipment were safely stowed in the hold and we began to look around the vessel that was to be our home for the next nineteen days.

For a long time I watched the crew taking on the cargo. Here were real Africans at last, instead of the Harlem blend familiar to me, and looking just as if they had walked out of the pages of Sir Harry Johnston's books on the peoples of Africa. Nearly all of them were vociferating loudly and constantly; this state, I soon learned, was the normal one for adult male Africans. After sunset the hubbub subsided for a while. A pious black Moslem spread his mat and prostrated himself toward the east. Various weird-looking hybrids came out of their holes below to sniff the evening breeze. To me the steerage is nearly always more interesting than the cabin, with the added advantage that black and brown deck passengers apparently do not resent being stared at, not even when making their simple arrangements for sleeping on the soft side of the forward hatch.

Just outside our cabin there was a passageway along which members of the crew passed back and forth at all hours of the day and night. Incredibly gruff and guttural voices assailed our eardrums and profaned the stillness of the calm night. Thinking out loud (if thinking is not too complimentary a term) began long before dawn and continued with but few interruptions until heavy sleep slowed down the vocal apparatus. But as there were always fresh relays coming and going, it was not the individual that counted so much as the mass effect, which was enough to ruin the disposition of an ivory Buddha. And if an hour before dawn there was a brief lull, the gang of deck-swabbers soon struck up their five o'clock chorus of scratching brooms, hissing and gurgling water streams, banging pails and raucous voices.

Nor did the pallid passenger get much

Photograph by J. H. McGregor

TWO DJIBOUTI BOYS ON THE DECK OF THE *CHAMBORD*

WHO SCALED THE SIDES OF THE BOAT AFTER SWIMMING MANY FEET UNDER WATER TO SEIZE COINS THROWN BY MEMBERS OF THE EXPEDITION.

respite during the day. If he tried to forget his troubles by writing, the ship's band soon drove him away from the smoking-room, where he had picked what looked like a less riotous corner. Up forward three or four morons were always slamming down heavy rubber disks on a resounding-board, applauding every hit or miss with clamorous mirth; tiny boys and girls romped and screamed, French and Belgian ladies exchanged lively barrages of articulate speech. At mid-deck the second-class passengers were driving a scratchy phonograph. The cabin down below, besides being frightfully hot, was within the sound of noisy black imps that were forever jabbering over their tasks.

One of the chief events of a long day in the Mediterranean and Red Seas was hustling down to an early continental breakfast in one's pyjamas. Only one

member of the expedition ever succeeded in overcoming his inhibitions (if he ever had any) enough to conform to this custom. The rest of us were too much bound by the tradition that pyjamas of varied hues and stripes were made only to sleep in; and frankly we lacked courage to appear in public *en déshabillé*. It was surprising, however, how spruce and well tailored some of our fellow passengers looked in these garments. One wondered if they had put them on only when they got up. At a *petit déjeuner aux pyjamas* a gentleman would, of course, never venture more than a discreet and furtive glance at the ladies, as they appeared one by one on the grand stairway; if the truth were told, one furtive glance was too often enough. Then, after conquering one's own violently anti-social feelings, if one attempted a feeble pleasantry for the benefit of the lone Englishman across the table, his impassive rejoinder made one realize that after such a night and at such an abominably early hour even the "autocrat of the breakfast table" would have found it seemly to refrain.

But just as sickness and adversity turn some men toward religion, discomfort often makes it easier for some to seek release in work. My lethargic conscience reminded me of a series of three articles on "Basic Patents of Evolution," which I had long since solemnly promised to write. Accordingly I set to work each day after breakfast and, with much time off for slothful ease, found the nineteen-day voyage only just long enough to complete my stint.

After a few days in the Mediterranean we went through the Strait of Messina and with our field-glasses studied the passing panorama of buff and gray mountains and the shore, dotted with flat-roofed houses. The serrate peaks gave evidence that the whole country was largely made up of volcanic ash and indeed one mountain especially looked like the core of an ancient volcano. Now a volcanic country is often an unstable country, sinking and rising above the sea-level over long ages. This brought to mind the conclusion of paleontologists that there was once a land-bridge from north Africa through Malta, Sicily and Italy, which permitted the ancient Italian elephants to invade Africa, leaving the extinct pigmy elephants of Malta on the road. Had the ancestors of the chimpanzee and gorilla reached Africa over the same route, or had they come across some old bridge near Gibraltar, coming down from Spain and working their way along the west coast, thus reaching the Congo Basin by a roundabout route?[2]

After many days we saw at last a long thin line stretching out to meet us from Egypt. It was the gigantic stone breakwater leading to the Suez Canal; soon a heroic statue of De Lesseps welcomed us to this broad highway of East and West. And what a procession it was that passed us: first, a broad-beamed ship from the Dutch East Indies, with flat-faced Malay ex-pirates squinting cheerily over the rails; next a dingy Portuguese collier; then an immaculate Scandinavian with two rosy-cheeked ladies as the only visible passengers. Quite naturally one thought of mighty seas and romantic shipwrecks, of the castellated sea-caves off the Tasmanian coast, of Cocos Island and its pirate's harbor.

After coming into the harbor of Port Said we picked our way among the crowding ships and stopped a little way from the wharf, with which we made contact over a row of pontoon floats. The Egyptian warehouses and other

[2] Evidence against both these possibilities has since been discovered by Mr. Hopwood of the British Museum (Natural History), who has found fossil jaws and teeth of primitive chimpanzees in east Africa. This makes it appear probable that the anthropoid apes came in from the northeast, perhaps through Arabia, along with many other species of forest-living mammals and birds of Eurasiatic origin.

Photograph by J. H. McGregor

BOYS IN THE SANDY STREETS OF DJIBOUTI

THE VILLAGE IS UNBELIEVABLY HOT AND DRY, AND BARE OF VEGETATION.

buildings near-by looked ample and dignified because they had very high stories and high narrow windows. We were then boarded by haughty Egyptian officials and their black assistants in red fezzes and flowing white robes. We seized the opportunity to go ashore to do some shopping and I bought an excellent pith helmet at a very reasonable price.

Late that night from a huge coal barge along our side a line of human ants swarms up the steep planks, bearing in baskets heavy loads of coal which they cast down into our bunkers. Shafts of white light from the ship pierce the swirling clouds of black dust and glint from the coal-coated bodies of the toiling athletes. The vocal alarms of our crew are as nothing to the pandemonium raised by these devils with their confused shouts and chanteys. For hours they descend into the pit and reascend; their

huge chief, like the mighty prince of darkness, rages and bellows above them all.

By daylight we are slipping gently along the canal, at first past fields and grassy banks.

We pass a craft with high curved prow and slanting sail; as when Pharaoh's ships went forth in search of gold and frankincense.

Then come salt marshes, stretching interminably; upon them is the abomination of desolation.

Sand dunes and ever more sand dunes; a lone dromedary patiently crops the withered roots.

A hissing locomotive and its train rattles past us; it pours forth great rolls of smoke and shatters the stillness and peace of the desert.

Twisted strands of rusty barbed wire stretch across the sand; old snares where men's bodies were caught during the war in the desert.

In the distance an immense pylon rears itself high above the plain; as we drift by we pay a silent tribute to the memory of those who fell defending the canal.

We stop; ships pass us, one by one; we go on in silence.

The end of the canal; a monument with a fierce lion guards the highway of the nations.

We go up out of Egypt into the Red Sea; but for us no wonders are shown, where once Pharaoh and his mighty hosts were swallowed up.

A hot wind blows upon us as from a fiery furnace; we wilt, but our complaints avail not.

The sands of the desert rain down upon us; they fall alike upon the just and the unjust. The land is far away, yet are we covered with dust like weary travelers. The sun is hidden by the yellow fog. The sea is leaden, yea, it gleams like ancient silver.

In vain the musicians sound the loud timbrel and the harp; we rally not at the blaring of the trumpet.

The heathen grind the noise-box; they disquiet others but bring unto themselves no peace.

They that smite the sackbut and the dulcimer insult the ears of the righteous; but no man rises up to curb them.

Women pant for the water brooks; the thirst of men is not assuaged by cool wine.

For the desert afflicts us in the night season; and by day its wrath lies heavily upon us.

Rough Eritrea now blows her hot breath against the sail, warning the mariner away from her hostile shore. But we sail on in the black ship.

Then Djibuti, where in the smooth harbor comely boys, black as to skin but of noble mien, befitting the offspring of Hamitic warriors, dive with glad cries into the dark blue sea; and they, swimming downward, seize the coins thrown from the many-decked ship; as when a flock of fleet-winged marine birds contend for the small fish, after having dived for them; and great is the clamor thereof.

We sail away and the cool south wind blows upon us; we cross the equatorial line, while foolish mummers profane the ancient Neptunian rites.

Many nights pass, while the Southern Cross climbs higher in the sky. Then one day Mombasa's harbor opens. "Africa, we are here."

THE RAREST OF THE OCEAN SUNFISHES

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AMERICAN MUSEUM OF NATURAL HISTORY
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INTRODUCTION

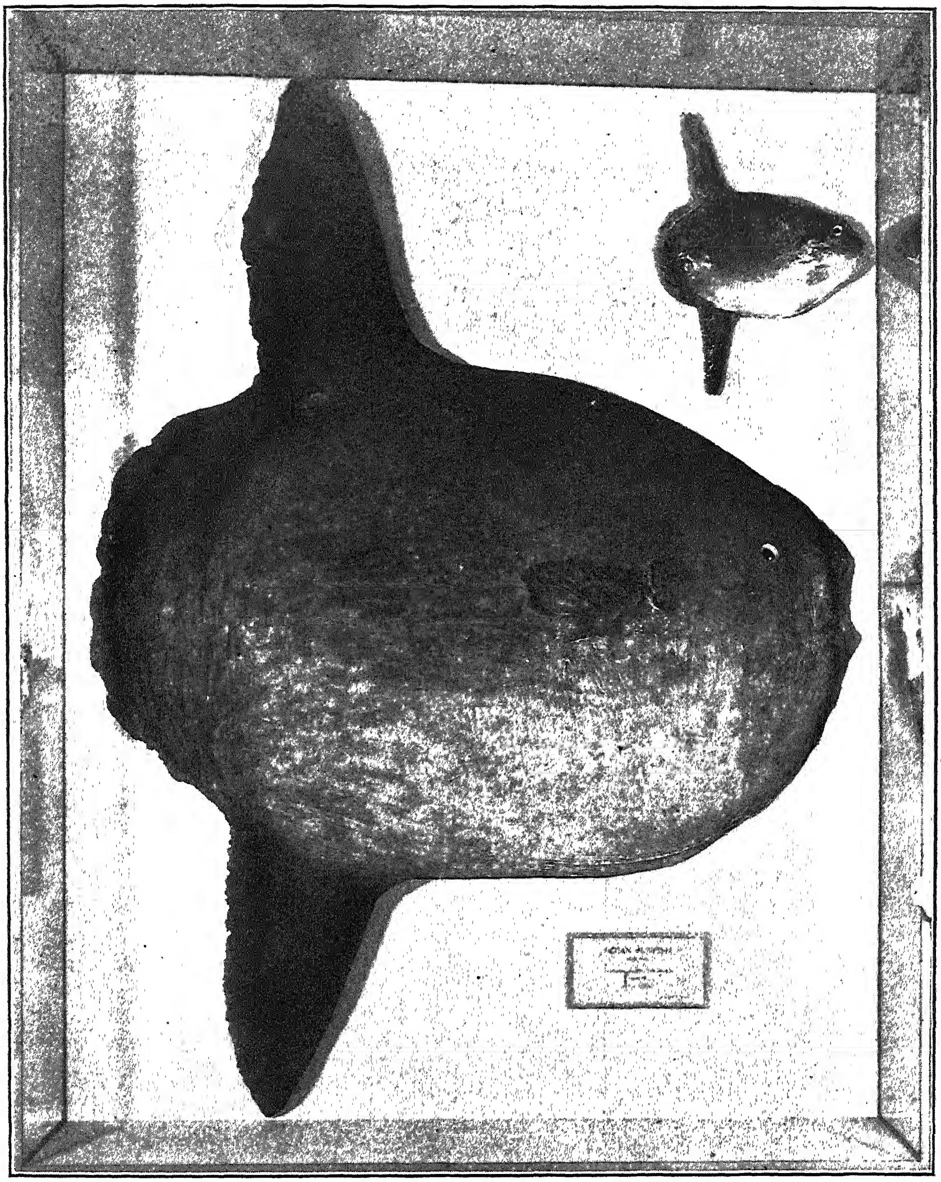
THE sunfishes, whether of fresh- or salt-water, are all, as their common name signifies, short and deep-bodied fishes. The fresh-water forms are probably known to most readers of this journal, not so, however, the marine fishes. The fresh-water sunfishes, while having bodies deep in proportion to their length, have all the fins that fishes have and have true fish-tails. Not so the marine forms which make up the family Molidae (Latin *mola,* a mill). The millstone-shaped fishes lack the pelvic fins and have the whole hinder part of the body, that behind the dorsal and anal fins, *i.e.,* the tail proper, so reduced, so telescoped, that the dorsal, caudal and anal fins are brought together so closely that one can with difficulty say where the dorsal leaves off and the caudal begins, and where this ceases and the anal begins—as the reader may see in Fig. 1. Further, the caudal fin is reduced to a mere rudimentary stump—least so, however, in the form (*Masturus*) which we are going to consider. As we shall see, the tail in this form is more extraordinary than in either of the other genera.

The ocean sunfishes are divided into three genera—each containing but one commonly accepted species. In order to make clear the relationship of the three genera to each other, it will be necessary to figure and very briefly describe the first and second kinds—the third, our fish, will be fully described with many figures further on.

The commonest and longest known of the ocean sunfishes is the round-tailed form, in which the tail and caudal fin are reduced to a mere rounded stump. This fish is commonly known as *Mola* (*Orthagoriscus*) *mola* (*rotunda*). These formidable names are interesting, as a trip to the dictionary will show. Three of these names are given to the fish because it is round, as may be seen in Fig. 1—a photograph of mounted specimens in the American Museum. The word *Orthagoriscus* means a sucking pig and was applied to this fish because of its bulky body, slightly protruding pig-like mouth, and of the allegation that it grunts like a pig. It was known to the Romans and was first figured and scientifically described in 1554 by two of the "Fathers of Ichthyology"—Rondelet, a French doctor, and Salviani, a Roman physician.

The pointed-tailed ocean sunfish is surely often confused with the round-tailed form, but neither of them is likely to be mistaken for the peculiar oblong or truncate fish portrayed in Fig. 2. Here the oblong, narrow body and the obliquely cut tail definitely mark it off from the other forms. However, although *Ranzania truncata* lacks a tail, it does have something of a tail-fin composed of fin-rays enclosed in a membrane. Furthermore, this form is small in size compared with the others. A glance at Fig. 2 makes clear the significance of its specific name. Its "front" name was given in honor of the Italian naturalist, Ranzani, who published on ocean sunfishes about a hundred years ago. The fish was first figured by another Italian naturalist, Aldrovandi, in 1613.

Having made clear the curious and abnormal forms of two members of this family, we are now ready to introduce our readers to what is seemingly the rarest and certainly the least known of the millstone-shaped fishes. This form is ichthyologically known as *Masturus lanceolatus,* and of it there are but 17



Photograph from American Museum

FIG. 1. THE ROUND-TAILED OCEAN SUNFISH, *MOLA MOLA*
MOUNTED SPECIMENS OF ADULT AND YOUNG IN THE AMERICAN MUSEUM.

specimens on record at this writing. These cognomina are interesting as their derivations show—Anglo-Saxon *maest*, a mast; + Greek *ura*, tail: Latin, *lanceolatus*, a little lance. These redundant names emphasize the curious pointed tail seen in the numerous figures to follow. The fish has been known for an even 100 years, having been discovered at the island of Mauritius in 1835.

We trust that the publication of our figures and descriptions of the pointed-tailed ocean sunfish may lead to a wider knowledge of it and to the sending in to the American Museum of other photographs and accounts of its occurrence on our coast and elsewhere.

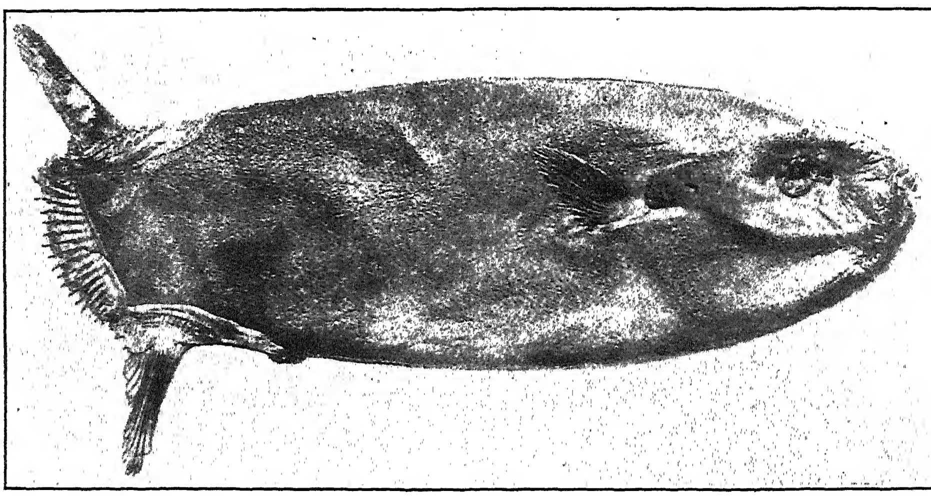
PUBLISHED RECORDS OF THE POINTED-TAILED SUNFISH IN FLORIDA WATERS

In introducing this fish to our readers, there are first to be presented three published but little noticed accounts and figures of this fish in the coastal waters of the peninsular state. Next, accounts of new and numerous specimens will be set forth with illustrations from photographs.

YOUNG SPECIMENS ON THE WEST COAST

Off Pensacola: This chronological account very fortunately begins with the figure and brief story of a baby specimen. For this record we must go back to 1889.[1] How little this fishlet was may be seen in Fig. 7, where it is portrayed in natural size. It was one of four small sunfishes taken from the stomach of a dolphin (the fish, not the mammal) captured off Pensacola in March, 1882. It is of marked interest in two particulars: in the spots on the upper and hinder parts of the body—forerunners of what are found on the fresh-caught adult; and even more interesting is the whiplash composed of three elongated rays coming out just above the center of the caudal fin. This is a characteristic feature of the tail of all the young of this form, and is a prognostication of what is found in the tails of all adults.

These most interesting little fishes are preserved in the collections of the Civic Museum of Natural History of Genoa. They vary in size from about $1\frac{1}{2}$ to 2



After Steenstrup and Lütken, 1898

FIG. 2. THE TRUNCATE–TAILED SUNFISH, *RANZANIA TRUNCATA*
CONTRAST THE OBLONG BODY OF THIS FISH WITH THE ROUND BODY OF *Mola mola* IN FIG. 1.

[1] Described by A. Perugia in *Annali Museo Civico Storia Naturale Genova.*

inches long—not counting the whiplash, which was found to grow progressively shorter in the larger ones.

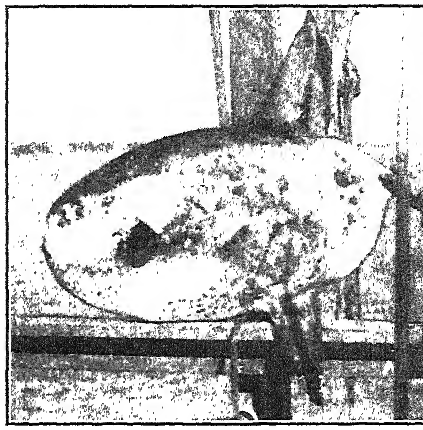
Adults on the East Coast

Heretofore adult forms have been as few and far between as have the young ones. But two grown fish from these waters have ever been recorded (one of them under a wrong name). These will be noted and then there will be listed two old museum specimens which have for long years remained unknown and unrecorded—in part at least because wrongly labelled. Lastly, four new nondescript fish will be described and figured from the finest photographs ever made of the pointed-tailed ocean sunfish.

At Palm Beach: The first record of such an east coast fish is found in the publication in 1918[2] of a figure of a specimen captured at Palm Beach in that year. This figure, which is erroneously labelled *Mola mola,* is of a *Masturus*, as may be seen in Fig. 3. It is unfortunate that the fisherman, to steady the fish for the photographer, should, of all parts, have laid hold of the point of the tail, thus obscuring it. However, there is here a rounded point or lobe or "spade" projecting beyond the general rounded contour of the tail-fin. Faintly to be seen are spots on the dorsal fin and on the body—especially on the venter. Beyond the fact that this fish was taken at Palm Beach in 1918 there are unfortunately no data whatever.

At Daytona Beach: In April, 1931, a giant pointed-tail was taken near Daytona Beach. It had been left by the ebbing tide in a "low water slough" 5 or 6 feet deep, where it could thresh around but could not get away. In this it was captured by the fishermen. Entangled in their seine it was dragged ashore and with much effort was transported to a pier where it was put on exhibition. This pointed-tail, one of the largest

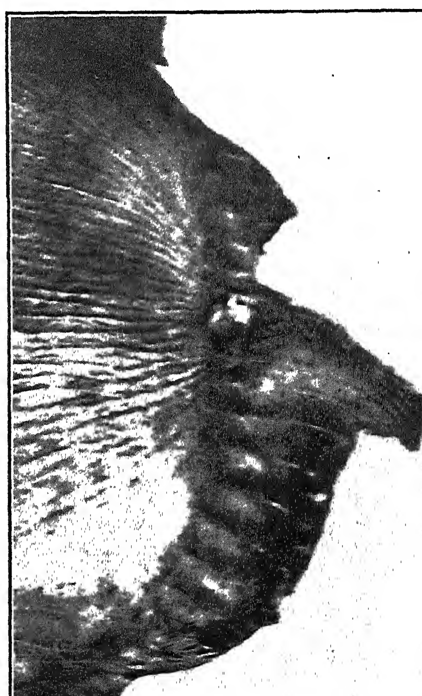
[2] Dr. C. H. Townsend in the *Bulletin of the New York Zoological Society* for November.



After Townsend, 1918

FIG. 3. A ROUND-TAILED SUNFISH TAKEN AT PALM BEACH

Note the round point of the tail held by the man's hand and the faint spots on the body.



Photopragh by S. R. MacDonald, 1935

FIG. 4. ANOTHER PARTIALLY DRIED TAIL OF AN OCEAN SUNFISH

Compare this (Miami No. I) with that in Fig. 9 (from Daytona Beach).

specimens on record, was 8 feet 4 inches in "over all" length (of which the caudal fin measured 2 feet 2 inches), and the total depth of this fish (nearly round in outline) over the dorsal and anal fins was 8 feet 9 inches.[3]

The weight of this giant was estimated as at least 1,200 lbs. Great difficulty was had in handling it, and unfortunately no derrick was at hand for swinging the fish up for photography. This is a great misfortune to ichthyology, since this fish is not only one of the largest on record but also is the most beautifully spotted and colored of any specimen known to us. However, it is fortunate that MacDonald was at hand with a camera, and that he made every effort to get photographs showing as much of the body as possible. Fig. 5 is a head-on view of the fish, lying on the floor, showing the great size and the stretch of the dorsal and anal fins. Behind is the great spade-shaped caudal lobe, the point of which, however, does not show.

A better idea of the size of this giant may be had from Fig. 6. Here note the huge anal fin and the enormous tail—the great caudal lobe being unfortunately not shown in the photograph. The tail is separated from the body by a band, and everywhere are the spots so characteristic of the species. The tip of the caudal lobe had apparently been broken and had then healed. This mutilation (shown clearly in Fig. 8) could only have been effected by a shark or a barracuda (a fish even more dangerous than a shark). And just here it may be remarked that the figures of the pointed part of the tail of nearly every known specimen of this species show more or less mutilation of this part.

A photograph of the dried tail taken a year later is shown in Fig. 9. Here the hooked form of the central part is well portrayed, as are the fin-rays of the whole caudal fin and particularly the 5 in the lobe. Their absence from the center of the "point" is significant. There is reason to believe that here the rays are quite slender, and that in this dried tail they have gone to pieces and have fallen off. Unlike what is found in other specimens of the pointed-tailed sunfish, the hook here points downward.

The shape and the internal make-up of the tail are matters of prime importance in studying *Masturus*. Since these structures are wonderfully well shown in the tails of Florida specimens, we call particular attention to them.

UNDESCRIBED POINTED-TAILS FROM THE EAST COAST

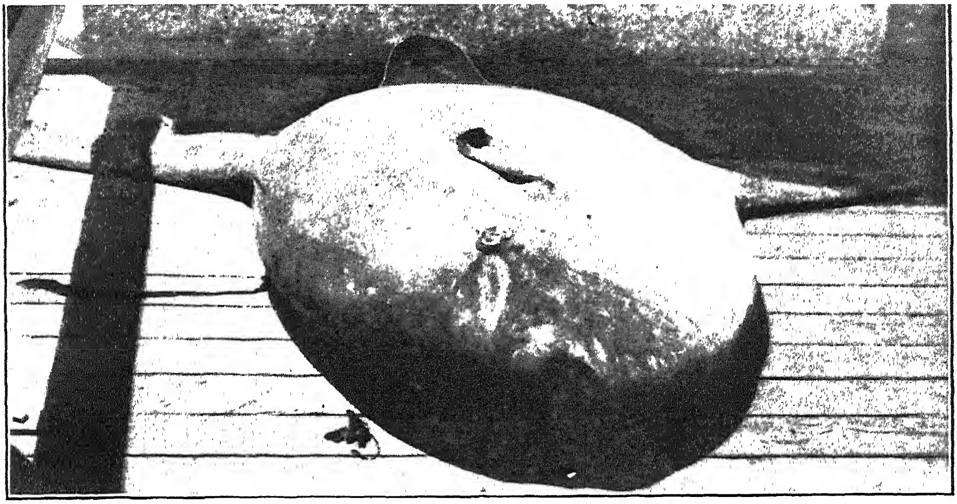
We have now come to that part of our article in which we will first describe some specimens taken long ago in northern Florida, wrongly named and never put on record. Then we will describe and figure four fine fish taken in southern Florida in the late winter of 1935.

Specimens at St. Augustine

At the "Alligator Farm and Museum of Marine Curiosities" on Anastasia Island at Saint Augustine are two mounted ocean sunfish labelled *Orthagoriscus mola*. However, these are pointed-tailed sunfish which will now be put on record.

The larger and older of these two fish (Fish No. I) was stranded on St. Augustine Beach in 1912. It is reported to have been 10 feet long and 11 feet 3 inches deep over dorsal and anal fins. Its weight was estimated at 1,700 lbs. Even now, after 24 years of drying and shrinking, it measures 8 feet long and 9 feet 7 inches deep. A photograph shows the remains to be in bad shape, the fins being dried and fragmented. A great enlargement from this negative shows the battered tail fin to have the unmistakable internal structure of that of the pointed-tailed sunfish. The lobe is badly torn, but in the enlargement it is seen to be composed of 4 or 5 rays, like those

[3] Record was made of this huge fish in *Copeia* by Hubbs and Giovanoli in 1931.



Photograph by S. R. MacDonald, 1931

FIG. 5. THE DAYTONA BEACH OCEAN SUNFISH, 1931
HEAD-ON VIEW (FROM SOMEWHAT ABOVE) OF THE FISH LYING ON THE DOCK. NOTE THE SPADE-LIKE TAIL (POINT INVISIBLE).

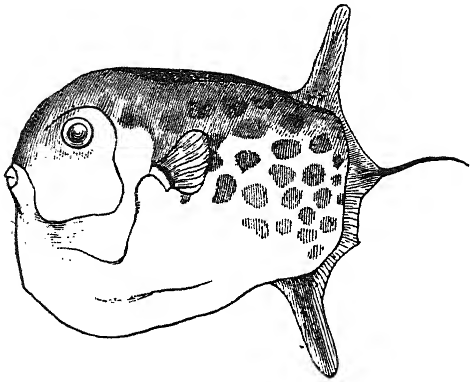
shown in Fig. 9. Thus the internal evidence (internal in the literal sense) makes us sure that this is our ocean sunfish—the largest that has ever been recorded. With so many fine photographs of other pointed-tails at hand, it would be an anticlimax to reproduce the photograph of this battered fish. The structure of the caudal is so fragmentary that not even a line drawing can be made.

One of the owners of this museum[4]

[4] Mr. George Reddington, formerly connected with Ward's Natural Science Establishment at Rochester, N. Y.

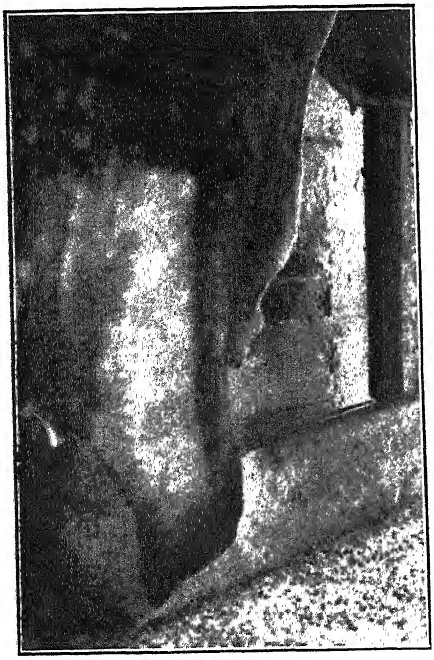
Photograph by S. R. MacDonald, 1931

FIG. 6. QUARTERING VIEW FROM BELOW OF THE DAYTONA GIANT
NOTE THE HUGE ANAL AND CAUDAL FINS (THE TIP OF THE LATTER UNFORTUNATELY NOT SHOWN).



After Perugia, 1889

FIG. 7. A YOUNG POINTED-TAILED *MASTURUS LANCEOLATUS*
NOTE THE WHIPLASH TO THE TAILFIN AND THE SPOTS ON THE UPPER AND HINDER PARTS OF THE BODY.



Photograph by courtesy of Leonard Giovanoli, 1931

FIG. 8. TIP OF TAIL OF DAYTONA FISH
NOTE THE DOWNWARD SWING OF THE MUTILATED LOBE.

writes that his recollection of the tail of this huge specimen is still fairly clear, and particularly since the fish was photographed and hundreds of post cards sold. He sends a pencil sketch and states that in the fresh fish the point of the tail extended 12 or 14 inches beyond the general contour of the caudal fin, and that the essential tail structure was identical with that of his other fish (Fig. 14). Since this is the largest pointed-tail ever taken, a figure of this giant is a great desideratum, and every effort has been made to find either a copy of the photograph or of the post card—but in vain.

The other sunfish (Specimen No. II) in this same private museum came ashore on St. Augustine Beach in 1929. Its total length is about 6 feet, and its depth over unpaired fins is 7 feet 8 inches. It has 18 tail-fin rays, about 7 of these in the "spade." The fish is so hung that the photograph made of it is not good enough to reproduce. But from it, however, a tracing has been made of the dorsal-caudal-anal region. This is reproduced as Fig. 14. Here may be noted the extremely long (and narrow) dorsal and anal fins, making the depth of the fish greater than the length. The whole caudal is unusually wide, recalling that of the Daytona specimen (Fig. 6). Especially noticeable is the long narrow pointed lobe placed above the general level of the body and cocked upward. This is in part due to shrinkage consequent on drying. Let the reader compare this with the tail of the Daytona Beach specimen portrayed in Fig. 9.

Masturus AT MIAMI

The months of January, February and March, 1935, were remarkable for the capture of four fine specimens of the pointed-tailed sunfish in this region, and for reports of twice as many more seen but not captured. The junior author was fortunately on the ground with

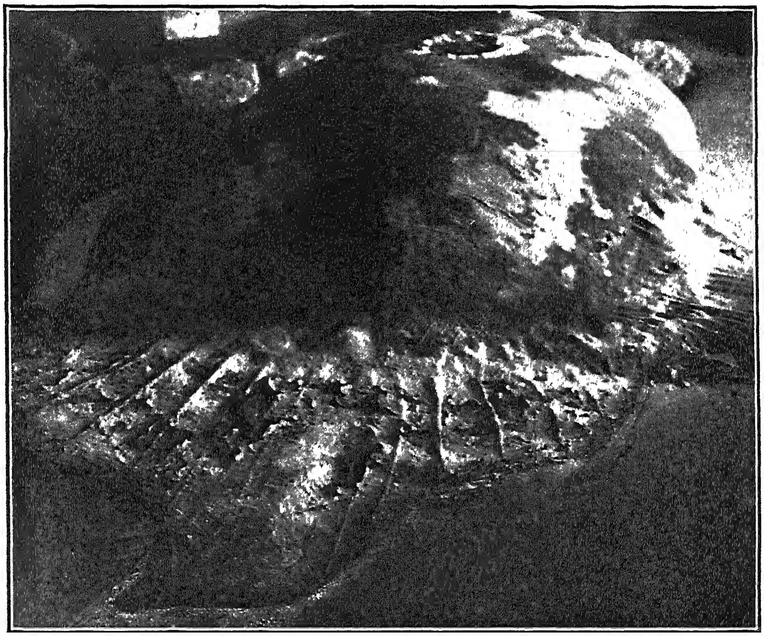
camera and notebook to record this remarkable abundance. These fish will be reported on by number in the order of capture.

For the first pointed-tailed sunfish (Fish No. I) MacDonald wrote under date of January 14:

Verily the Lord loveth us. During the early afternoon of January 11, while driving up the ocean boulevard about 15 miles north of Miami, suddenly, right before my astonished eyes, hanging on a post, I saw a *Masturus lanceolatus*. Think of it, there right out of a clear sky with no effort on my part was this much-desired pointed-tailed sunfish waiting to be photographed. This was done at once, as you may see from the enclosed print [Fig. 10]. I also made measurements as follows: total length 3 ft. 11 in.; height over dorsal and anal fins 3 ft. 11.5 in.; estimated weight 100 lbs.

Here is the story of its capture as given me by the owner of the fish. On January 9, he and two other men were out in a small fishing boat in the edge of the Gulf Stream about 4 miles from land and some 16 or 18 miles north of Miami. The fish when first sighted was swimming upright with its dorsal fin out of water. The power was shut off and the boat allowed to drift. The fish, seemingly curious, circled the boat several times and finally came close enough to be reached with a boat-hook used as a gaff and was hauled aboard. As it came over the side, a sucking-fish about 9 inches long dropped out of one gill opening. The fish was then brought ashore and hung up by a rope run through the body near the tail as shown in the picture.

In their first attempt to hang the fish, the men perforated the tail too near the edge and tore out a piece of the fin. This maltreatment shows clearly in all the photographs [*i.e.*, in Fig. 10]. The wrinkled condition of the skin is due to the suspension and to drying.



Photograph by S. R. MacDonald, 1932

FIG. 9. DRIED TAIL OF THE DAYTONA POINTED-TAILED SUNFISH

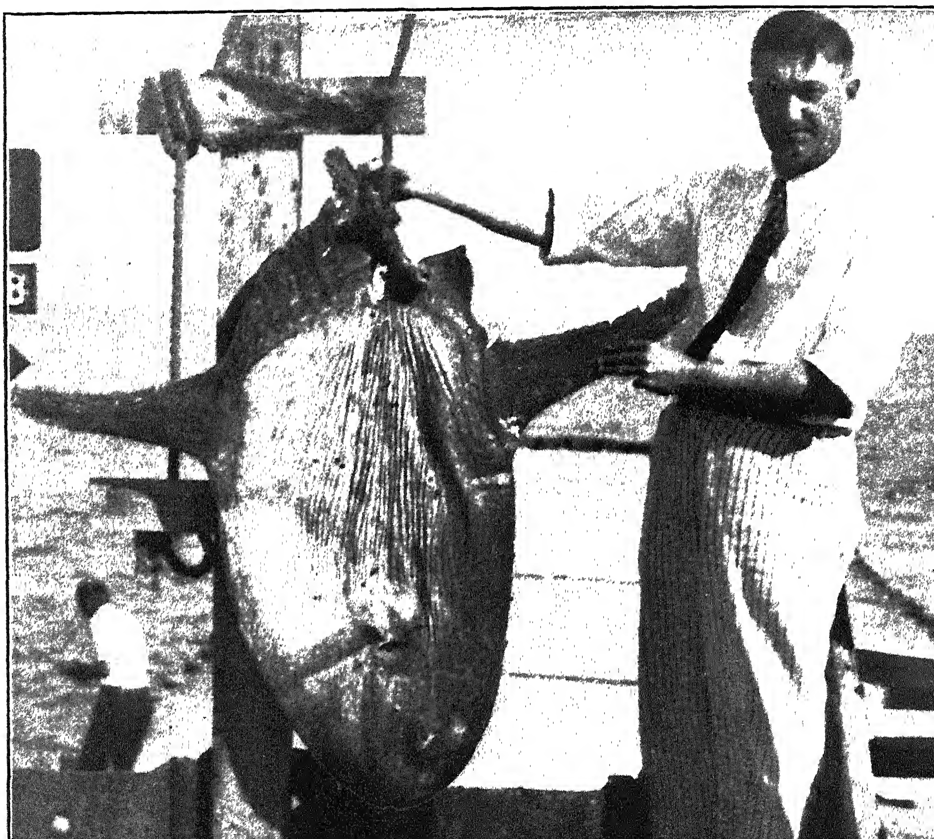
THE DRYING OF THIS TAIL HAS BROUGHT OUT THE FIN RAYS, SOME OF WHICH IN THE CENTER ARE MISSING. COMPARE THIS FIGURE WITH NO. 8

This photograph shows the features described in the preceding paragraphs. The upper part of the caudal fin has suffered much mutilation, but the "spade" or "thumb" is held by the junior author's hand just to the left of the suspending rope. Note the spots on the white part of the body. Some can be

seen on the dorsal and anal fins. The tail fin is divided into two parts—a thick inner part and a thinner outer. The whole tail fin is so thickly covered with large irregular spots that these sometimes become confluent and make blotchings.

of the tail shown in Fig. 4. Here may be made out 6 thread-like rays, essentially similar to those seen in Fig. 9. No other figures of the tail showing these structures have ever been published.[5]

On January 19, MacDonald wrote:



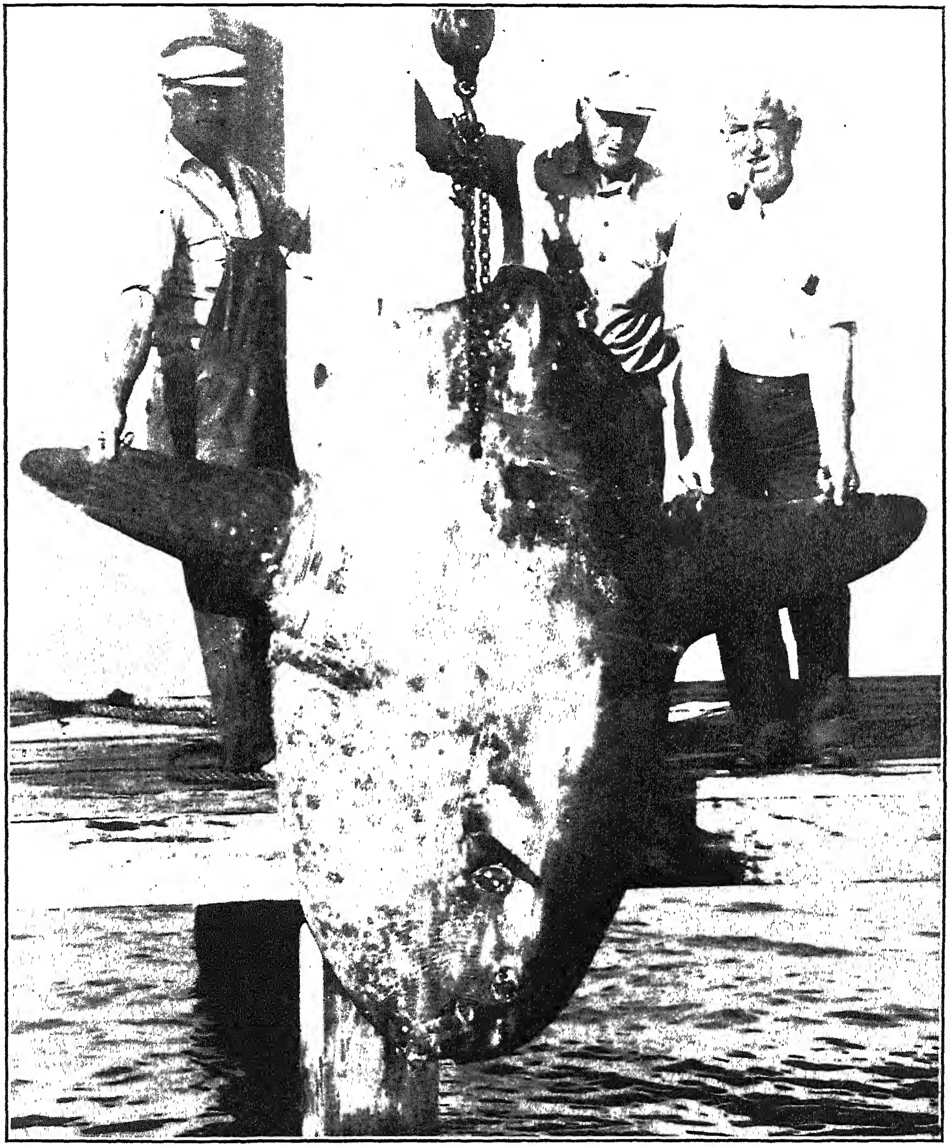
Photograph by Mrs. S. R. MacDonald, 1935

FIG. 10. THE FIRST MIAMI *MASTURUS* AND THE JUNIOR AUTHOR
THE TAIL HAS BEEN BADLY MUTILATED IN THE EFFORT TO SUSPEND THE FISH.

Since our chief interest in this fish is concentrated on the anomalous tail structure, a photograph was made of its tail after drying had been going on for several days. This photograph (*mirabile dictu*) shows faintly but definitely certain internal structures. Since the reader's attention has previously been called to these, it is again directed to the point

"This locality seems to be *Masturus* Highway. A second fish, and a big fellow, was captured yesterday—6 ft. 4 in. long and 8 ft. 3 in. deep, estimated weight 500 lbs." A photograph of this fine fish is shown in Fig. 11.

[5] The fish later came into possession of Mr. Albert Pflueger, naturalist and taxidermist of Miami, who plans to mount the skin and display it in his private museum.



Photograph by courtesy of Major F. P. Bradford, 1935

FIG. 11. PORTRAIT OF MIAMI OCEAN SUNFISH NO. II

NOTE THE STUBBY TAIL AND THE SPOTS ALL OVER THE BODY. THE HEIGHT OF THE MEN GIVES A "YARDSTICK" FOR ESTIMATING THE SIZE OF THE FISH.

This second sunfish (Fish No. II) was taken in the northern end of Biscayne Bay close to the outlet to the ocean known as "Baker's Haulover," about 5 miles north of Miami. It was seen floundering about in shallow water, and two men went out in a skiff, shot it and then brought it in and swung it up by a derrick, as the figure shows. The tip of the tail is short and rounded and has evidently been mutilated. It is even shorter than the tail of the Palm Beach fish (Fig. 3). Such abbreviation is common in the tails of most specimens of the pointed-tailed sunfish figured and described.

The third pointed-tail (Fish No. III) was captured on January 28 on the inside edge of the Gulf Stream, a little south of the mouth of Miami Harbor. It was seen swimming slowly about with its dorsal fin out of water, and was so unafraid that it allowed a large fishing boat (110 feet long) to approach it near enough for four men to secure it with long-handled gaffs. The captain of the boat reported that its sides were iridescent, with blue spots showing distinctly. These have faded, as Fig. 12 shows. The total length of the fish was about 7 feet, the "over all" depth was but 2 inches more and hence this millstone fish was almost round in outline. In the figure the dorsal and anal fins are curled backward, so one can not estimate the true depth. Its weight was variously estimated at from 700 to 1,000 pounds.

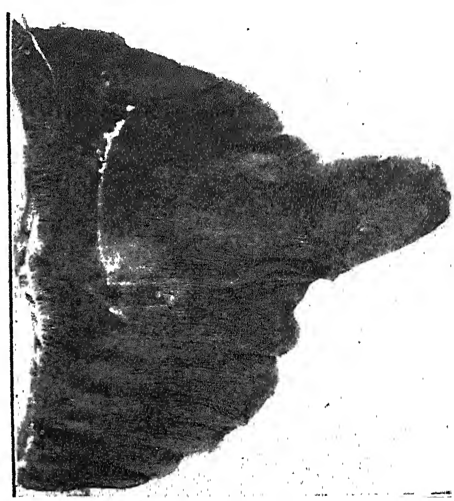
When brought ashore, the specimen was not swung up high enough for the tail to clear the ground (Fig. 12). However, the three unpaired fins were cut off and sent to the American Museum—a wholly unique gift, since there are literally no others in any museum.[6] These fins came in perfect condition, and the tail fin was photographed, as may be seen in Fig. 13, the only photograph showing the fresh fin known to us. The general shape of this fin is accurately shown. Above

[6] For these fins and for photographs of this and other Miami specimens, the American Museum is greatly indebted to Mr. Pflueger.

Photograph by S. R. MacDonald, 1935

FIG. 12. OCEAN SUNFISH NO. III, MIAMI, 1935

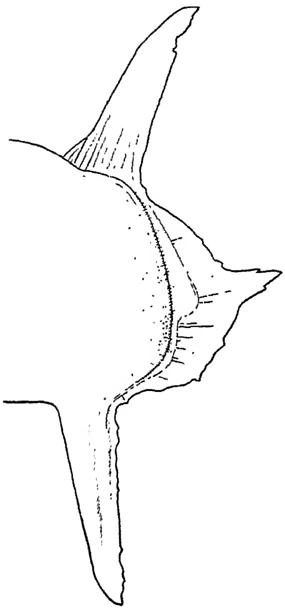
THIS IS THE LARGEST SUNFISH (ABOUT 7 FEET IN BOTH HEIGHT AND DEPTH). THE POINT OF THE CAUDAL IS NOT CLEAR OF THE SAND.



Photograph by H. S. Rice

FIG. 13. THE WHOLE TAIL INCLUDING THE "SPADE" OF FISH NO. III

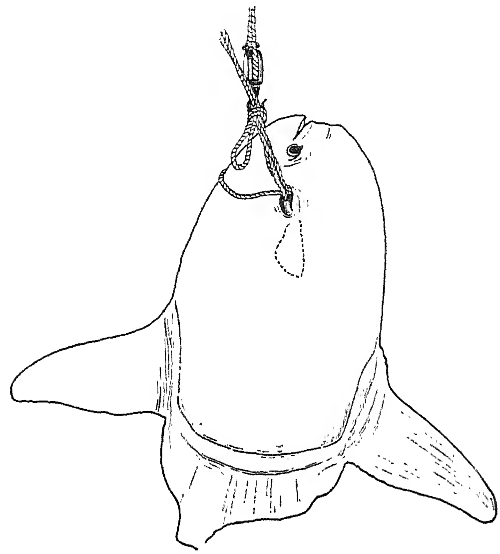
NOTE THE UPTURNED CAUDAL LOBE. THIS FIGURE OF THE TAIL FIN IS UNIQUE—THE FIRST ONE EVER PUBLISHED.



Sketch from a photograph by S. R. MacDonald, 1935

FIG. 14. OUTLINE SKETCH OF TAIL OF ST. AUGUSTINE FISH NO. II

NOTE THE SLENDER DORSAL AND ANAL FINS, AND THE WIDE CAUDAL FIN WITH ITS TILTED LOBE.



Sketch from a photograph by courtesy of Albert Pflueger, 1935

FIG. 15. OUTLINE SKETCH OF MIAMI *MASTURUS* NO. IV

THIS FISH HAS A LARGE TAIL FIN, THE LOBE BEING ABOVE THE MEAN LEVEL OF THE BODY AND TILTED UPWARD.

the median level is the spade-like lobe which points somewhat upward. Later this tail will be dissected for the muscles and then deeper for the fin rays. It is expected that these dissections will help reveal some of the relationships of this interesting sunfish.

Just here fate overtook us—the junior author was laid low with the influenza for about 30 days. But even from his sick-bed he wrote that the captain of the boat which captured our third fish reported that on February 11 he saw a school of 8 pointed-tailed sunfish disporting themselves in the Gulf Stream. This man certainly knows our fish, and his testimony indicates its presence and abundance off Miami.

Another fine specimen (Fish No. IV) was harpooned on March 9 in the ship's channel at the south end of Miami Beach, connecting Biscayne Bay with the ocean. When sighted it was swimming upright in the water, not on its side. Two sucking-fish were found in its gills. These fish are constant companions of the ocean sunfishes, and it is commonly alleged that they are of one specific kind—*i.e.*, that the sunfish acts as host to only one particular species of sucking-fish. This is a very interesting matter but one which can only be settled by examining a large number of such "suckers" which are definitely known to have been obtained from particular ocean sunfishes.

We had bad fortune with this specimen. MacDonald was at San Marco on the west coast of Florida and missed it entirely. Gudger was spending a short vacation at Sanibel Island higher up on the west coast. Pflueger telegraphed Gudger on Sunday, March 10, but it was impossible for him to go to Miami that day. And finally on the late afternoon of March 10, the fish had become so offensive that it was necessary to heave it overboard.

The photograph of this specimen was not taken until the great fish had lain long on the dock and had got in bad condition, hence it is not suitable for reproduction. However, it is valuable to show the proportions and the form and the set of the fins, and from it has been made the outline drawing shown in Fig. 15. This shows that the caudal lobe arises above the median level of the body and points slightly upward. The extreme end has surely undergone abbreviation. This caudal lobe markedly resembles that of the second Miami fish (Fig. 11). Unfortunately, no measurements of this fish were made, but judging by the men beside it in the photograph, it must have been between 7 and 8 feet high and perhaps a foot less in length. Its estimated weight was put at about 600 pounds, and this is presumably not an exaggeration.

Comment should be made here that all these pointed-tailed sunfish at Miami swam slowly about with part of the dorsal out of water. They are poor swimmers, are sluggish and inert. They seem unafraid of men and boats, have little hesitancy in approaching them, and when a fish is gaffed, harpooned or lassoed it makes no resistance other than an effort to get away. Practically nothing is known of its life history, save that its very young are totally unlike the older young—*i.e.*, they undergo a distinct metamorphosis. The senior author is making a special study of the structure and development of the tail in both very young and in adults. When published it is hoped that this study will throw much light on this extraordinary organ.

HOW THE POINTED-TAILED SUNFISH HAS REACHED THE COASTS OF FLORIDA

This question has long ago been asked by the reader, and we will now endeavor to explain the occurrence of the fish in such numbers in Florida waters. But first it must be noted that for the other side of the Straits of Florida, Luis Howell Rivero[7] has recorded the capture of a fine specimen near Havana. Further, he has kindly let us see an article now in press describing five other fishes of this genus taken near Havana. The occurrence of these six northern Cuban specimens ties up absolutely with our eight records set out above. All might be called "Straits of Florida specimens," and the occurrence of all fourteen fish can be accounted for by one explanation.

Johannes Schmidt, the Danish oceanographer, by the capture of a large number of larval and post-larval *Masturus* in the Sargasso Sea, has shown it to be a breeding place for this fish. Many young specimens of different ages have been reported from this great "dead water" of the north Atlantic. Adults in the southern parts of this sea might stray into the North Equatorial Current of the Atlantic, and be carried by it between the various islands of the West Indies, into and through the Caribbean-Gulf waters, and out via the Gulf Stream between Cuba and the Florida Keys. Thus the four little ones taken off Pensacola came to that region and thus Rivero's six adults were brought to the Havana coast of Cuba. Thus also the four Miami fish, the small Palm Beach specimen, the Daytona giant and the two St. Augustine specimens, were distributed along the east coast of the peninsular state.

That numbers of pointed-tailed ocean sunfishes have been taken along this very coast and mistakenly identified as the round-tailed form, *Mola mola,* can be little doubted. And now that the pointed-tailed sunfish is being recognized as such when and where captured, it may be confidently expected that other specimens, and possibly in fair numbers, will be reported from the east coast of Florida.

[7] *Memorias de la Sociedad Cubana de Historia Natural* for 1934.

THE HEREDITY OF THE MODERN BED—AND ITS INBORN WEAKNESSES

By Professor DONALD A. LAIRD
DIRECTOR OF THE PSYCHOLOGICAL LABORATORY, COLGATE UNIVERSITY

How and why things start is often lost in obscurity, yet it is origins which explain many puzzling things. I have buttons on my coat sleeves because sleeves used to unbutton to make it easy for swordsmen to roll up their sleeves. The back of my coat is split because years ago a split coat was helpful when transportation was chiefly on horseback. On every hand we can find such illustrations of vestiges we have inherited from previous generations, vestigial characters which were once useful, but which no longer appear to serve a purpose. We are heirs of the past, and its obedient slaves.

The quest of origins, the attempt to find out how and why things started, is unexpectedly practical. It is always a fascinating venture. Mankind's curiosity about how things started and how they changed through the course of history seems never to be satiated. Perhaps it is never fully satisfied because of the gaps in written history and the long puzzlings necessary to unravel the still older unwritten history that is revealed in the mounds, village ruins, burial places and fossil remnants of more ancient ways of living.

The gaps in the story of men's resting places are mostly prior to the Bronze and Iron Ages. Archeologists and antiquarians have given us a fairly complete story of mankind's sleeping practices for the last 20,000 years.

Earlier than that there is no significant record, and probably for the obvious reason that man had not yet invented the bed. These remote ancestors of ours had invented fire, and were weaving clothing for themselves before they discovered the helpfulness of a bed in their daily rest and recuperation.

Around a million and a half years ago pro-human families lived in the plains of central Asia. Their beds were nests in trees. The important thing in their existence was safety from prowling night animals that threatened their security of life. So they slept in trees.

The next advance in habitations, and we can not quite call them human habitations yet, was to take refuge at night in natural shelters. Years later our pro-human ancestors discovered they could make their own protections out of stones. These earliest houses—if we may call them houses—were in fact hiding places in which one could sleep in relative safety.

Our very word bed is derived from an Indo-European word root meaning "a dug-out place for safe resting." And to-day, a million and a half years since our forerunners built simple stone defenses for their sleeping places, we nevertheless find some human hesitancy to sleep in an upper berth or in the top of a double-decked bed, for fear of falling out.

It may be the expression of a remote ancestral trait which prompts most of us to lock our bedroom doors and not to open the windows too wide—while a few of us so prize a safe place for resting that each night there has to be an inspection to make certain no one is under the bed.

Perhaps the biggest achievement of all time was early man's invention of fire. This changed the type of food he consumed. It made it possible for him to start migrations and to live in regions

which would have been hostile without the blessing of fire. As he moved from the temperate and uniformly mild regions which cradled the race he felt the need for clothing. Fortunately the frontal lobes of his brain had developed sufficiently so that he was capable, not only of throwing animal skins over his shoulders, but could invent—as he did—looms on which to weave textiles. Needles were used by men and women of the late Stone Age, less than 30,000 years ago. And they were weaving cloths on looms some 20,000 years ago. Some of these looms which are now in museums can be used for weaving at the present day.

All these interesting developments by our remarkable ancestors made it inevitable that sooner or later they would make use of beds. But there is one thing we must mention, because it was of cardinal significance in leading these primitive people to want to have something special on which to sleep.

Pro-human men had a stooped posture. It was natural for them to sleep or rest in a semi-curled position, and the nest in the crotch of a tree conformed to his natural posture. That was around a million years ago.

The visual lobes at the back of his brain developed, and early man started to make increasing use of his sense of vision. He began to stand erect in order to peer into the distance to locate enemies or food. By the time he had invented the needle and loom he was of fairly erect stature and found it somewhat uncomfortable to curl up in his sleep. He could curl up, but he doubtless found that when he did he awoke with muscles stiff and joints sore from the stretching into unnatural positions. He was developing to walk erect, and to sleep straight he needed a bed of some sort. A hammock, with its gracefully curved position, would have been tailor-made for the sleep of his pro-human ancestor, but not for our man of the late Stone Age.

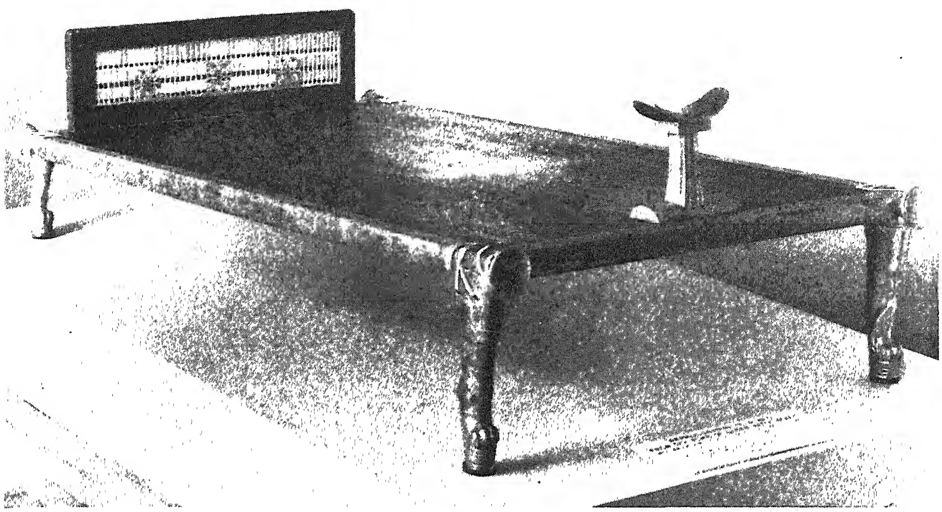
So some 20,000 or so years ago this Neolithic man provided a place for sleeping in his huts. Elevations at one end of the single room which constituted his home were used for sleeping. Furs and coarse textiles were used for coverings; the mattress was crumpled grasses or leaves; the springs were the hard ground. All in all, this was doubtless comfortable so far as warmth was concerned, but I feel safe in imagining he often wished for a hollowed-out spot in which he could place the downward arm.

This first sleeping chamber of the race made it possible for Neolithic man to sleep with his spine in more or less of a straight line. His changed habit of life, with its erect walking, made this more or less of a necessity, and his new-found way of sleeping straight undoubtedly helped him to walk straight and erect.

I presume none of us would wish to exchange sleeping places with this long removed relative of ours. But I wonder if perhaps he was not pretty well off at that? To be sure, the solid earth of the sleeping elevation of his hut was hard and unyielding, and the little space was so narrow that he very probably rolled out of bed many times; but despite these foreboding aspects, I think this old Neolithic man, with his growing craftiness and culture, had good sleep. His life was simple, of course, and he had very few worries to keep him from sleeping.

And, above all else, he had the splendid sleeping habit of spending more time on his rough and uncomfortable bed than most of his nieces and nephews do today. All during the darkness he slept, and if he did not sleep he was at least quiet and resting from twilight until sunrise. He had regular hours of retiring and the desirable habit of long hours of sleep or rest.

Then his invention of fire began to cut his sleep short. It was so enjoyable to sit in the carefully nourished glow of the fire and chat, keeping one eye on the precious fire lest it die out, while the



Courtesy, Museum of Fine Arts, Boston

A BED OF THREE THOUSAND YEARS AGO.

THE SLOPING, HARD-BOTTOMED BED WITH AN EQUALLY FIRM NECK REST TO PROTECT THE COIFFURE, USED BY QUEEN HETEP-HERES I, MOTHER OF KING CHEOPS OF THE FOURTH DYNASTY. THIS IS A REPRODUCTION OF THE ORIGINAL REMOVED FROM THE TOMB; THE ORIGINAL BED IS IN CAIRO.

other eye was kept on the fringe of darkness watching for pairs of spots with a greenish glow which would reveal the presence of some prowling enemy.

Mankind no sooner began to make significant inventions than, lo and behold! these began to work against him as well as for him. And civilization ever since has been largely a compromise between the pros and cons, the virtues and the evils, of inventions.

First it was his precious fire that began to undermine man's hitherto good sleep habits. A few thousand years later tallow candles and whale-oil lamps made it still more pleasant to stay up. Then kerosene displaced the candle in adding to the cheerful brightness of the night, only to be displaced in turn by electricity, which can turn night into day and which has turned the sleeping habits of thousands of persons topsy-turvy.

But that is getting a little ahead of our story. When mankind began to cut short its rations of sleep, it began to discover how uncomfortable the sleeping elevations were. And they quite naturally noticed that they got more tired during the day. So what is more logical than, as the late Dr. Walter Hough, of the Smithsonian Institution, discovered, for women of the Stone Age to invent chairs after their mates had previously built beds of a sort.

The bed antedates the chair by many centuries, but the first chairs were more like the chairs of to-day than the beds were like the beds of to-day. As soon as primitive man started to civilize himself he robbed his night sleep and took to inventing beds so he would sleep better, and chairs so he could rest more during the day. He must have been altogether human!

The earliest written record of beds is probably that found in the Book of Esther. Coarse stuffed pillows or cushions were piled in a corner of the room to be used as beds at night and as seats in the daytime.

In the Bronze Age, which reached its zenith in Egypt, we discover that inven-

tiveness had hit upon the idea of making these sleeping elevations movable, like a chair, so they could be put at any place in the house—this may mark the beginning of the practice of rearranging the furniture every few months.

But the Egyptians were as artistic as they were ingenious. Exquisitely fashioned from rare woods, ivory, bronze, copper—even of gold and silver—their beds became objects to gaze upon and admire so that their resting qualities became almost secondary. Solomon's bed was made of cedar of Lebanon.

A strange thing about these Egyptian beds is that they are practically all single beds, and narrower than our single beds of the present day. There were a few wider beds, and also a few which were so tall that a ladder or special steps were needed to climb up to them.

The typical Egyptian bed was a narrow affair, half bed and half couch, which was used as much for daytime lounging in their languorous climate as it was used for night-time sleep. There are records, also, of what we might call sleeping porches in Egypt. Cleopatra had one. Her bedroom lacked nothing in art and luxury. Her bed was made of ivory and gold, and was of an immense size. It was covered with silken throws, embroidered with gold cord. A gold god of love, a yard tall, stood on the footboard and aimed a golden arrow at his sleeping mistress. On the piazza just outside her bedchamber there was an equally luxurious outside bedroom. This forerunner of our sleeping porch contained a bed made of marble and gold. Here the Serpent of the Nile rested on hot nights.

That was how royalty slept in the late Egyptian civilization. Narrow beds were being abandoned, and a curious development had started which persists in vestigial form to-day, like the dueling buttons fashion still keeps on men's coat sleeves.

Outdoor sleeping had its advantages in those ancient days on the Nile, and it had a number of disadvantages, just as it still does to-day. To protect the sleeper from the burning sun and the inclemencies of weather, a canopy overhung the bed. The corners of the bed were extended up into the air and a canopy of silk or linen was suspended between these corner posts. That was the highly practical beginning of the four-poster bed so cherished in to-day's tradition. A netted tent of linen gauze also enclosed Cleopatra's bed to provide protection against insect pests.

The origin of the canopy, or tester, was thus plainly a practical necessity. Long after the necessity had ceased to exist, the canopy and overhanging drapes were retained and developed, especially by the French courts, into highly decorative appendices of no practical use whatever.

The first bed springs, if we may call them such, were devised by the Greeks. Most of their beds were narrow, serving as a lounging couch by day, but they discovered there was more comfort if the top of the bed was made of bands of stout leather, laced between two heavy boards at the sides of the bed. When covered with skins this was much more comfortable than skins placed on top of a marble or bronze slab. That simple bedspring of leather thongs remained the only spring foundation until such a recent date that many persons remember the change. But that is getting a bit ahead of our story.

In the later Greek civilization considerable luxury was developed around their sleeping paraphernalia. Pillows, especially, were developed; Corinth and Carthage became famous as places which, among other things, made wonderfully comfortable pillows. Small apartments must have developed also, for their vase paintings record folding beds.

The early Romans slept on mattresses stuffed with reeds, hay, wool or feathers. The cotton mattresses which the Egyptians had developed were too difficult for the Romans to obtain. The Roman beds

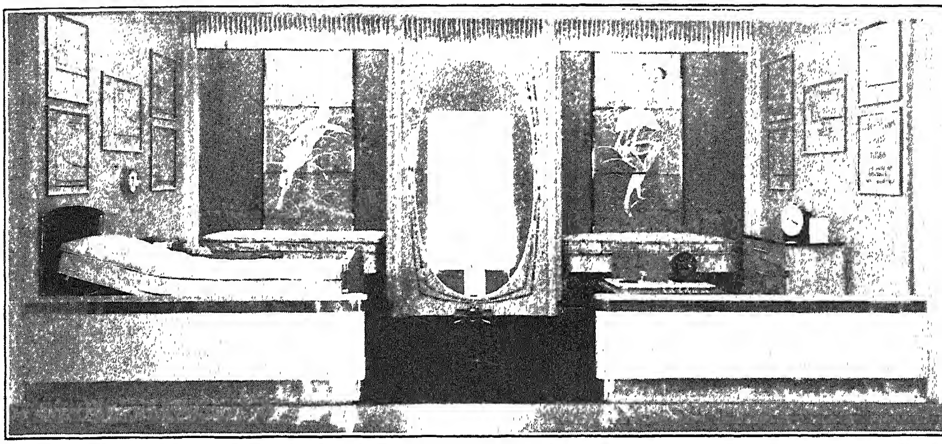


EXHIBIT OF SLEEPING EQUIPMENT AND THE METHODS OF STUDYING SLEEP
PREPARED BY THE AUTHOR FOR THE CENTURY OF PROGRESS EXPOSITION.

were usually narrow ones, and of considerable height from the floor—the height from the floor showing the Egyptian influence.

The height—so great as almost to make a person nervous—was a precaution which was started to keep rodents and snakes from getting into bed. Just as in the northern European countries, at about the time the Roman civilization was at its zenith, heavy railings were built around the bed, and the home—whether hovel or palace—was overrun with large dogs of the Great Dane and mastiff strains as a protection against wolves. Practically everything about a bed frame which we have to-day had some useful purpose of this sort at the inception, although it may be purely decorative to-day. It is little short of amazing how through hundreds of centuries the original meaning of a bed as a safe place for resting is clearly shown in the architectural features of the bedsteads which were shortly to become elaborate and enormous things.

There was a break in progress after the fall of the second Roman Empire. Practically every civilized accoutrement disappeared in the wanton confusion of the early Dark Ages—although in the northern portions of Europe the Vikings were calmly using wooden bedframes filled with generous feather mattresses from about the eighth to the eleventh centuries. The rest of Europe, however, was sleeping on the hard ground. Everything was chaotic, and living reverted to the most primitive terms.

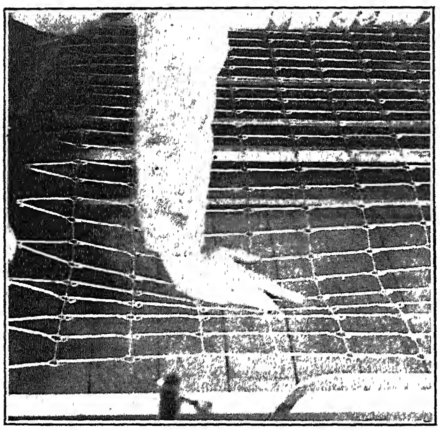
A bench, a chest, a few skins and, with a favored few, some pieces of linen, constituted their complete living equipment. The chest was a veritable Pandora's box. In it were stored almost all their worldly possessions. In the daytime it was used as a table. At night a few skins were spread over it, and, presto changeo! it became their bed. Those not fortunate enough to have prior rights to sleep in the elevated security of the chest top, had to content themselves with wrapping in skins on the floor. When linens were available, the average person undressed for sleep, wrapping his naked body, mummy-like, with large linen cloths, perhaps to keep the furs from tickling.

Then civilization slowly reestablished itself, human life and property became more secure, and people stopped their wandering existence. In the thirteenth century all luxuries increased. The Pandora's box grew, and as it enlarged it changed its form into the crude bedstock.

The first bedstocks were movable struc-

tures, since the possibility of forced moving and wandering with all one's possessions was still in the backs of people's minds.

With the growth in political stability, however, the bedstock became an integral part of the house. It was built into one corner of the room as a permanent part of the walls themselves. Perhaps some traveler brought back accounts of such beds, or in some monastery a studious monk had translated records which told about the bed niches in ancient Pompeii.



THE LINK SPRING DEVELOPS A PERMANENT SAG.
THIS IS HOW EVEN A BRAND-NEW ONE SAGS WHEN IT IS SLEPT IN.

At any rate, the influence of older civilization was manifest, the bedstocks became highly ornamented, and the old canopies and protective curtains were gradually revived as they could be afforded.

Not yet did homes have bedrooms. The ideal purposes of a separate room for sleeping was achieved indirectly, through the growth of decoration. From the built-in bed, resembling our modern railroad or steamship berth, the separate bedroom developed through the decorative impulses. Carved panels were added to the bed niche, it was built out farther into the room, heavy draperies were later added to curtain it off, in Scotland, Brittany; in Holland folding wooden shutters were used in place of draperies, and these folding shutters can be seen to this day in many of these old sleeping places. But the bed had become so bulky and formidable an object by this time that it occupied most of the room. There was not space for other furniture, and without realizing it people had developed bedrooms.

The elaborate carvings in northern Europe, and the paint and gilt decorations in southern Europe had not been born to die unseen, however. For centuries the bed remained the prized piece of furniture, not so much for qualities promoting rest as it was a possession of luxury to be displayed in all its beauty to make one's friends envious.

Louis XIV had 413 beds, many of them enriched by embroideries in pearls on a background of silver or gold. The carvings were by Proux or Caffieri, while the gilding was by La Baronniere.

The nobility received distinguished visitors in their bedrooms, and in General Grant's day, modesty being more cherished, beds were made of elaborate walnut carvings with an upholstered seat built in at the foot of the bed, so visitors could be received in one's bedroom but without the embarrassment of the host being in bed. This suggests that the rumble seat started in the bedroom.

During the gorgeous monarchy in France there was no blushing about using a bed as a comfortable throne from which to converse with visitors. The term "bed of justice" developed from the custom started by Louis XI of having his own bed in parliament on which he reclined, while the princes were seated, the great officials standing and the lesser officials kneeling. Petitions were heard, ministers instructed and courtiers visited while the regent or host enjoyed the soft comfort of feather bed and silken pillows.

Hard-headed northern Europe, however, was meanwhile developing ideas to make the bed more restful. And to this

day in Scandinavian countries we can still see the sloping bed they developed. This bed was made at an incline, so that the sleeper's head was higher than the hips, and the hips higher than the feet. Sloping in some examples most precipitiously from head to foot, these beds became popular for the belief that they drained the phlegms from the body and promoted better sleep. The circulation of blood was, of course, not discovered at this time.

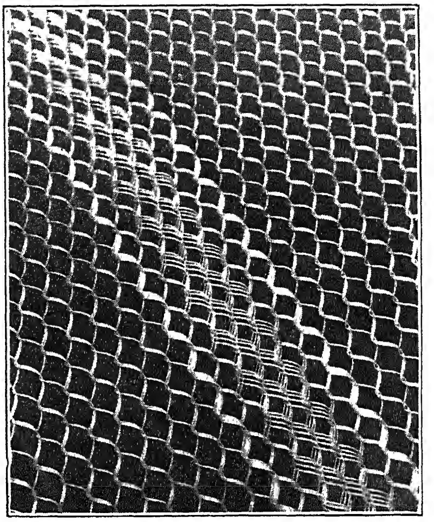
In the laboratory we have experimented with the quality of sleep while one is sitting up all night, and have found it is of a rather poor sort. We have not yet experimented on sloping or tilting beds, but it is undoubtedly worthy of study.

Louis XIV may have possessed 413 beds, but the English at about the same time had no need for such a large number. In an efficient fashion the English particularly developed a type of bed which certainly should have been safe resting places, so far as there is safety in numbers. Let us draw a background for appreciating this rather spectacular development.

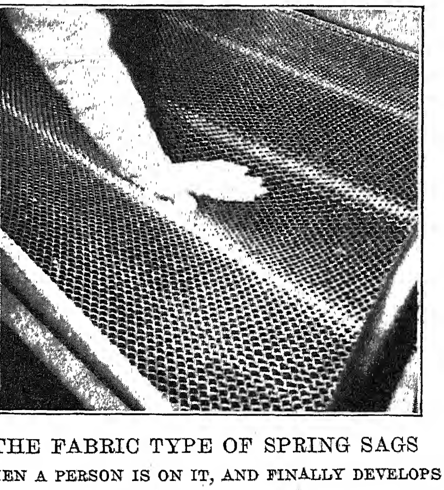
We usually think of a Roman bed as a couchlike affair, of rather narrow proportions, which was used for eating as well as napping. This evolved into the Roman triclinium, or three-sided bed, which extended around the three edges of the table, leaving the fourth open for the slaves to serve the viands.

The English development some 1,500 years later was also a three-in-one bed, called Trinity. Of ample size, the high top layer of the bed provided a sleeping place for the immediate members of the family. To be pulled out at the side was another mattress, equally ample, which was used by the favored attendants or for the overflow from the family itself.

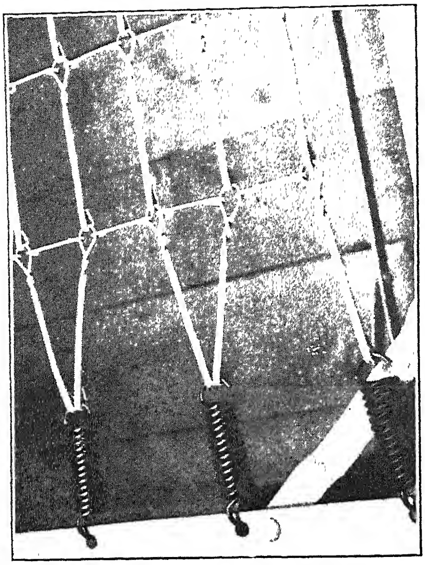
And at the foot of the bed a lower level was pulled out, still of ample size, which was used by the servants. Thus did the English go in for efficiency rather than for a great number of beds. In fact, they had few beds, typified by the condition in some of their castles, where out of 40 rooms only 8 were sleeping rooms. These old trinity beds still furnished adequate sleeping space, and when unexpected guests arrived there was always room to be found for them on one of the top levels of the bed.



A FABRIC TYPE OF SPRING.
THIS IS THE CHEAPEST—AT THE START. I PAID $3.00 FOR THIS SPRING.

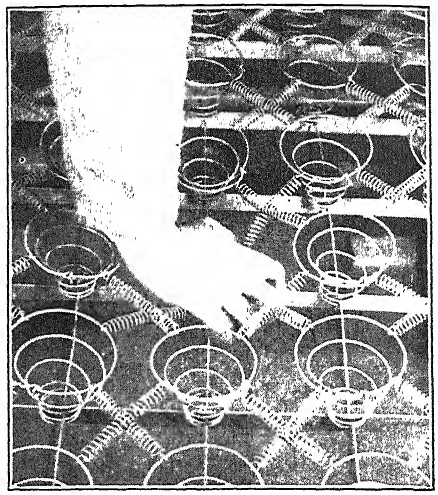


THE FABRIC TYPE OF SPRING SAGS
WHEN A PERSON IS ON IT, AND FINALLY DEVELOPS A PERMANENT HAMMOCK-LIKE SAG.



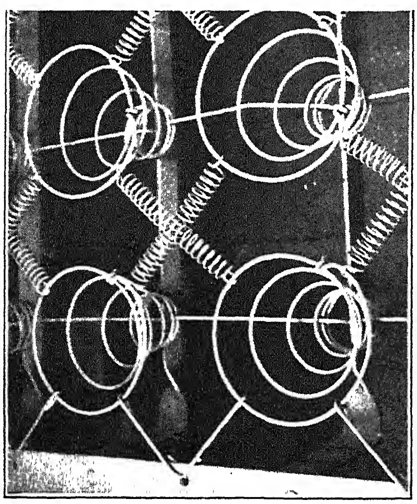
THE LINK TYPE OF SPRING.

THE HEAVY COIL SPRINGS HOLD THE LINKS OF WIRE TAUT. ON THESE, ONE MERELY SLEEPS ON TAUT WIRE.



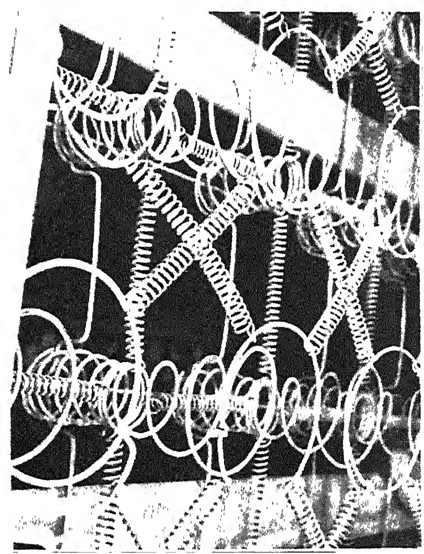
THE ACTION OF THE COIL SPRING

THE COIL SPRING, WHETHER SINGLE OF DOUBLE-DECKED, GIVES WHERE GIVE IS NEEDED, WITHOUT SAGGING. THE SHOULDERS AND HIPS, ON SUCH A SPRING, DO NOT CARRY MORE THAN THEIR JUST SHARE OF WEIGHT.



THE COIL TYPE OF SPRING,

MADE BY MANY MANUFACTURERS, IS THE BEST ALL-AROUND. THIS IS A CHEAP ONE; THE COILS ARE SHALLOW, BEING ABOUT FOUR INCHES DEEP.



A BETTER GRADE OF COIL SPRING.

THE COILS ARE ABOUT 8 INCHES DEEP, AND HELICAL IN CROSS-SECTION. TWICE AS MUCH SPRING IN THE SAME BED.

When the guests planned any lengthy stay, they usually brought along their own beds. This was common throughout Europe; the highways were filled with carts loaded with the beds of the travelers, reminding us of our own tourists a few years ago when tourist camps were at their height of popularity.

The old trinity bed, which is the obvious forerunner of our modern trundle bed and of the studio couch which can be expanded to make more sleeping space, reached its pinnacle in the famous Bed of Ware, which has been immortalized by Shakespeare and can now be seen, upon the payment of twopence, at Rye House, Roxbury.

Thirty years were spent by the cabinet-maker, Jonas Fosbrooke, in constructing this amazing bed. It was not the carving —of which there was much—that immortalized this bed. It was its size. The top of this bed could, and did, accommodate 68 sleepers. The trundle bed under it provided space for 34 others. A grand total of 102 could sleep in this wonderful bed of Ware, about which you can read in "Twelfth Night."

Rather too large for the modern-sized family, this bed so pleased Edward IV, to whom it was presented in 1463, that he promptly pensioned Jonas Fosbrooke for the rest of his life. And the royal chamberlain, of course, prepared a special list of rules of etiquette for the horde that could sleep in this marvel. I do not know whether this list contained instructions that all should turn over at the same time or not. And it is rather distressing to imagine how one restless sleeper would disturb the 101 otherwise sound sleepers. But it did afford the safety of numbers and leave the other rooms of the house for feasting and for the inevitable dogs.

It was obviously architecture rather than hygiene that developed beds up to the threshold of our times. Beauty of an heirloom rather than comfort seemed to be the motive. Display rather than relaxation, elaborate trappings rather than anything to give restful sleep.

The Greeks had used leather thongs, which had some resiliency and give, as a foundation for their mattresses. Mostly it was hard wood bottoms which were used, and on top of these sticks of straw, grasses, leaves or feathers were used—and these are probably still used more widely throughout the world to-day for mattresses than any other materials, except possibly cotton.

Although the resting qualities of beds apparently were not improved until very recent generations, men have tried ways of getting more rest out of equipment which really belongs to the ages. Charles Dickens, for example, always carried a small pocket compass with him when traveling, and would use this as a guide in having the bed placed so that his head pointed north as he slept. Some years before this time the Abbé d'Entragues slept with his arms tied above him.

At the time of Louis XVI an enterprising character, Cagliostro, had sold miraculous beds which he pretended would cure rheumatism; this amusing charlatan became so well known and his beds so popular among the credulous that Dumas used him as the central character in his delightful "Memoirs of a Physician."

And Merrie England—home of the famous and ample Bed of Ware—saw a revival of these supposedly healing beds in 1779 when impresario James Graham opened his Temple of Health in London and exploited his "celestial bed." The magic of Graham's cures and his celestial bed were claimed—by him—to assure one would live to be 100 years old. He must not have slept in his own bed, and not taken his own diet, for he died before he was fifty.

The Greeks, before the days of such fakirs as Cagliostro and Graham, had their sincerely operated Temples of

Sleep. To these Temples repaired those whose slumbers were disturbed, to be hypnotized by the priest and laid in a niche in a stuporous condition suggesting sleep.

But the black magic of mesmerized beds or hypnotized Greeks or even the scientific compass of Charles Dickens is a bit afield from our main story. It is to some epoch-making changes in the bed itself we must look for the changes which give our present-day—or rather present-night—comfort.

The leather-thong bed spring of the Greeks practically disappeared, but late in the Renaissance we discover that the hard board bed surfaces were being replaced by a network of ropes. These old rope beds, like the acrobat's safety net, had some stretch, but not as much rebound. After a few weeks they were stretched into a hammock-like sag.

It was a regular chore at house-cleaning time to enlist the services of a strong man to tighten up the slack. James Liddy did not relish this chore, any more than he enjoyed sleeping on a rope bed with a sag which folded him up like a half-closed jack-knife.

This James Liddy lived in a city which has peculiarly nurtured inventive minds. Dr. Guthrie had just invented the use of chloroform as an anesthetic only a few miles from Liddy's home at Watertown, N. Y., a city which was later to give the world the 5 & 10¢ store and shredded wheat. About 10 years before the civil war, Mr. Liddy, to whom each of us is immeasurably indebted, sat waiting for his wife. As he sat in the buggy he was struck with the superior comfort of the spring-upholstered cushions, and rousing himself slightly from his drowsiness the idea skyrocketed into his head: Why not use buggy springs in place of ropes to make beds comfortable?

In a spring wagon factory at Watertown he gathered together an assortment of old buggy springs and installed them in his four-poster bed to take the place of the annoying and sagging rope. That was the first bed-spring, a typical Yankee invention which was not patented and which quickly spread into thousands of homes. James Liddy should be among the immortals, but he remained a poor man all his life—a typical Yankee inventor.

After the buggy spring contrivances had been in use for a few years, Liddy worked out the idea of using spiral springs which every one has found to their lasting comfort is an improvement over methods of sleeping which for some 20,000 years had remained essentially unchanged until this inventive Yankee carpenter in northern New York state went to sleep in his buggy, all because his wife took an unusually long time on a shopping errand.

The spring is practically in universal use among civilized peoples at the present time. It has made more sleeping comfort than all other historical changes in beds and sleeping equipment. There is no magic to the bed-spring; all it does is to allow one to relax on a yielding surface, which supports the body uniformly and naturally in all positions and in all places. It gives a buoyant rather than a hard or misshapen surface to support the mattress which cushions our body.

Three general types of bed-spring have come into use since Mr. Liddy's original buggy spring. These differ as much in sleeping quality as they do in mechanical construction, and it is wise to be familiar with these three variants of the idea of buoying the body.

Each manufacturer as a rule makes all three types, to satisfy different markets, so in discussing the merits and demerits of the three types I am giving no testimonial for any manufacturer. What I am trying to do is to give the customer the help instead of the manufacturer.

The cheapest spring is the fabric or

woven-wire type. It is also the poorest on which to sleep. It is called the fabric spring because it is made from wires which are slightly coiled and woven as a cloth fabric would be. Cribs, baby beds and youths' beds are commonly made around this type.

It can be recommended for the crib or child's bed, if an especially soft mattress pad is used on top of the fabric spring. The fabric spring is not fit for human use, however, for persons who weigh more than 40 pounds. It does not conform to the body surface and it quickly develops a permanent sag, even when the bed is not occupied, a sag which can not be removed by tightening it at house-cleaning time the way grandfather tightened the old rope bed.

The link type of spring is usually moderately priced and has only fair sleeping quality. Being made from links of stout wire which are joined together, end on end, it received the appropriate name of a link spring. At the two ends this linked net is fastened to the framework by stout springs. Sometimes a few springs are used to attach the wire net to the edges of the frame.

What we sleep on in such a spring is, of course, taut wire. This has the same weaknesses as the fabric spring, but it usually does not sag as quickly when there is no weight in the bed. It does sag, however, when some one is in the bed. This is the spring type which is most widely in use at the present time—though it is essentially the same as the bed of leather thongs invented by the Greeks. Wire is used in place of leather.

During the Philippine insurrection narrow link spring beds with folding head and foot, such as many people use to-day on camping trips, received an unusual nickname which still persists. Distressed at the apparent discomforts of our soldiers, who had to sleep on the damp ground during the campaigns, an American woman, who spent the more important part of her life in the Orient, bought a shipload of these simple folding link spring beds, which were rushed to our boys. This woman was Helen Gould. And beds of this type are still known as Helen Goulds.

The most restful bedspring is the coil type. This was devised by James Liddy after his first work with ordinary buggy springs. It is appropriately named from the large number of vertical coil springs which are fastened together in various ways to give a sleeping surface which readily yields where most pressure is placed on it. It conforms to the body surface and body build of the sleeper, supporting rather than bending the body. If well made, it will not sag. Not all coil springs are the same; the size of the wire, diameter and shape of the coils, the number of coils, tempering and the methods of fastening the coils to one another all modify the stiffness or springiness of the completed bed foundation.

After one's first birthday, one should sleep on no spring but the coil type. As body build and weight change from decade to decade, changes may be necessary to secure a foundation which has the proper resiliency to take care of increased weight or altered distribution of weight. At ages of 8, 18 and 38 it is often wise to change the bedspring, just as the size of the pillow needs to be changed between the ages of 1 to around 15 or 16, the period when shoulder breadth makes marked changes.

The mattress and spring together, of course, give the buoyant quality—or lack of it—to our sleeping place. A "soft" mattress is needed more on the fabric or link spring than it is on the coil spring. What we should do is to start with a good coil spring and then find the mattress which gives the best sleeping comfort for the individual who is going to use it. This can be done only by lying on it—

and yet most springs and mattresses are unfortunately bought in the grab bag.

Use these tests to discover the right combination:

Do you sink down comfortably, and without a sag at the hips when you lie on your back?

Does the combination of spring and mattress remain somewhat firm so you can turn easily from the back to the side?

When on your side, does the shoulder settle in comfortably without twisting and without pressure?

Can you place the downward arm almost anywhere with comfort?

Does your hip sink down without your back sagging downward or being thrown upward?

Those things rather than sentiment or appearance should determine the value of a bed. Sentiment changes, but the basic rules of sleep persist. In 1858 two candidates debated in a small Illinois town. The dusty square was packed, bands blared "Oh, Susanna," and twelve-pound cannons saluted the arrival of one candidate on his special train. The other candidate, gangling and awkward, arrived, unsaluted, on the stage-coach. Seventy-five years later the beds on which these candidates spent that night were auctioned. The one occupied by Stephen A. Douglas brought $1.25. The bed Abraham Lincoln slept in before the debate brought $20.00. Beds and speeches both have endured. But to-day they make better beds.

The history of sleep to-day is being written on tapes in various laboratories, by automatic instruments which make an indelible record of turnings and tossings. As you write the history of your own sleep, I hope the accounts I have given you of how other people slept will make the history of your own sleep a chronicle of a Renaissance and not of a Dark Age.

Be an heir of the past, not a slave of it!

A PETROGLYPHIC STUDY OF HUMAN MOTIVES

By Dr. EDMUND B. DELABARRE
PROFESSOR EMERITUS OF PSYCHOLOGY, BROWN UNIVERSITY

Our title may seem to be as paradoxical as a "round square" and as futile as "frozen assets." Petroglyphs imply something stony and static. Motives in execution are fluid processes. Yet petroglyphs, like all finished works of man, are in a very real sense "fossil" motives, and can be used as one help in revealing what the living organisms were like.

This is a study of motivation. It does not contemplate a survey of the problem in all its aspects. Conscious motives for human behavior are innumerable and complicated, often obscure and ill-comprehended even by the doer, not easy to reduce to a few simple principles. Both the popular and the scientific observer of actions is subject to a temptation to recognize too few of the possible motives from which they may spring. One good approach toward understanding them is to limit consideration to a particular class leading to a single type of action and result, while acknowledging but not studying the many others which are effective in other situations. By such definite limitation to one or another of the objectives of human action, studied separately by investigators who can master the limited fields and come to a comprehensive understanding of the factors operative in them, we may hope eventually to unravel the intricacies of purposive motivation in general. There must be a slow accumulation first of clear knowledge about all types of individual cases.

Essentially, the problems of motivation are not resolvable completely in the psychological laboratory. Some ranges within its vast extent may be explored there, but not the entire field. To comprehend the intricacies of behavior, vision must not be limited by the walls of the workshop, but must aim, astronomer-like, to roam over the wide universe of action and accomplishment. The circumstances involved in the varied and un-imitable situations of actual living require study.

Moreover, in essence, these problems can not be approached by objective methods. What any one truly feels and desires and what he truly aims to accomplish may be inferred sometimes more or less accurately by the outside observer, *after* knowledge of subjective conditions and their objective expressions has been gained. It is only the feeler's and actor's own consciousness and trained introspection which can primarily supply any least inkling of what is going on as causative processes. However exact we may come to make our knowledge of "action currents" in functioning brains, these can never be interpreted as to their full significance except in the light of such introspective revelations. Introspection, but no more fundamentally than objective observation, may be subject to uncertainty and error. This is no more true in the one case than in the other, and there are criteria for evaluating the dependability of either of them. Both must be used and correlated. When we are equipped with well-trained introspective insight in regard to the inner happenings in a given field of thoroughly studied endeavor, we may then feel assured of having good grounds for acceptable inference from objective reports or records dealing with the same type of occur-

rences. The objective facts in this field are uncomprehensible and valueless except in the light of enlightened introspections already correlated with like objective facts.

An interest in petroglyphs has been forced upon the present writer by circumstances, and has led naturally to a consideration of all the kinds of motive which might have led to their production. One case in particular has been studied with especial reference to this problem. It does not exhaust all possibilities of motive that may have been causative factors in other cases with other content. So far as these others have been studied by the writer, their contribution to the problem will be considered. But there is no attempt to widen the field into a completely exhaustive inquiry.

Wide interest was aroused by the discovery in 1926 of a runic record on Noman's Land, a small island just south of Martha's Vineyard. The rock on which it is engraved lies on a boulder-strewn and storm-swept beach and bears the inscription "Leif Eriksson" in unmistakable runic letters and the date "MI" in Roman numerals. Opinions differ in regard to who carved it and when it was done. The writer's own opinion is that it was the work of some one within the present century. But other writers have expressed different beliefs. One attributes it to Leif himself or his Norse followers, and another to some later explorer of our coasts at some time within the sixteenth century.

Our problem is that of what might have been the motive of the unknown person who made the record, without consideration of the question about when or by whom it was done, at any time from the date of Leif's voyages down to the present. Looked at in this manner, we must admit the possibility of any one or a combination of a wide variety of different reasons for making the inscription. Other motives than these might operate in other cases. For a record with this particular content, we may rationally consider any one in the list which follows as one which under certain circumstances might have led to its production. For this purpose, we are assuming that we know nothing about it, which makes it impossible to entertain the idea that it may actually be of any age which the assumption of any particular motive demands.*

Both of the writers who argue against a recent date for the inscription assume that if it were made recently it would have to be regarded as a fraud, a fake, a hoax, a deliberate attempt to deceive. Here are a few of their expressions: "It is most unlikely that they (later persons) would have forged an inscription in such an inaccessible locality where there was such small chance of discovery. . . . It is out of the question for anyone who has ever seen the inscription to say that it is a later day 'fake.'" "The would-be perpetrator of a 'practical joke' would scarcely—unless possessed of an abnormally fine sense of artistry—leave it at a place not likely to be visited by observing persons, and at a spot where the chances are that the 'bait' would be invisible owing to the tide. . . . Anyone who would have taken the trouble to carve the inscription since 1837 would presumably have also undertaken the much lighter labor of first consulting a reliable reference book on runic lettering in order to get his lettering correct if he hoped to impose on the credulity of others."

This seems to be the usual attitude of people who discuss the matter casually. The writer meets it constantly. Almost every one says that if it was done re-

* This assumption is made for the purposes of this discussion only, in advance of inquiry into the actual facts. What the latter reveal, if anything decisive, is considered in a separate report upon the inscription, soon to be published in *The New England Quarterly*.

cently, then the thing is a hoax or a practical joke. This is altogether too simple a way to dispose of the question of motive. On discovering such a record as this, one might think of many possible reasons for its existence so long as he had not yet secured any decisive information making one or others of them inapplicable to the particular case. Some of them may seem very unlikely; some are closely similar to others, yet with a distinctly different nature as motives. Their enumeration is a question merely of the psychological possibilities, and one must consider all of them in order to judge the problem fairly. Such an inscription as this one, then, considered apart from the question of its actual origin, might exist conceivably as a result of the working of any one of the incentives in the list which follows.

(1) Desire on the part of an explorer to leave his signature, executed by himself or under his direction, as a record of first discovery; with or without the additional aim of claiming the territory for his own nation. This is so familiar a procedure that there is no need to dwell upon it. Flag almost always, a more enduring record often, is left by the discoverer of new lands. The Portuguese, for example, who at one time were the most active of the explorers of unknown regions, frequently erected a padrão, or stone pillar, suitably engraved, at prominent points. Somewhat similarly, early cartographers attached to their maps of newly found places a simplified representation of the flag of the country claiming the honor of discovery.

(2) In some cases the aim of the explorer might be to leave his name thus engraved, set up prominently in some conspicuous place, as a landmark for the guidance of future voyagers. In the days of Vinland exploration, when compasses were unknown and sailing-directions—if we may judge by what is retained of them in the Sagas which have come down to us—were extraordinarily inadequate, some such means of positively identifying a place when reached at last would have been useful. If Leif himself was the author of our inscription, and realized that others would be sure to wish to colonize the attractive land where he had erected his "Leifsbooths," he might well have been moved by this consideration.

(3) It might have been the work of a crew, shipwrecked in a remote and little visited region, who desired rescue and thus sought to attract the attention of any who might come in search of them. It might then serve also as a record of their fate, in case no rescuing party came in time. This would not apply in our particular case, for we know that nothing of the sort happened to Leif Eriksson. But if we did not happen to know that, this would be a motive that would have to be considered. In all probability it was the one which led Miguel Cortereal to carve his name on Dighton Rock in 1511. It is analogous to the flag of distress or the bonfires or the rifle-shots of numberless people lost in remote places.

(4) The moving impulse might have been none other than that common one which has led innumerable people, of all races and in all times, to write or carve their names or initials or personal symbols in prominent places everywhere. The world is full of such devices, often unhappily defacing the objects whereon they are recorded. Pencils, jackknives, chisels, flints, are and have been thus busy in almost every place where people congregate. Precious relics of the past are not infrequently desecrated and even utterly spoiled in this manner. Among other valued monuments, our own inscribed rocks often suffer this fate. Sometimes it is a more harmless diversion, when the recording surface has no value in itself. This was true, for in-

stance, in case of the ledges at Pipestone Quarry in Minnesota, where "it was formerly a custom for each Indian who came to the vicinity to transcribe his totem upon the rock."[1] It was true also of the once famous "Written Mountains" in Arabia, whose rocks and cliffs are generously engraved with "ancient unknown characters." These were exciting deep interest and speculation during the early eighteenth century, when it was widely believed that they were historical records of great importance, perhaps a confirmation of the wanderings of the Children of Israel in the wilderness; but it is now known that they were utterly trivial, such as names of passing travelers.[2]

This impulse to leave some personal record of one's passing, with no such object as is implied in our previous cases, is a form of ego-maximation, a gratification of the urge to attain some kind of prominence, even an easy and trivial one. It takes the most varied forms, of which initial-carving is only one. It may be a mere normal and idle whim; or it may be a form of compensation for inability to attain success and prominence in more worth-while ways. We see it manifesting itself in silly "showing-off," in contests for pie-eating or pole-sitting championships, in attracting attention and service by becoming an "interesting invalid," often entirely without realization that that is the only reason for one's illness. These tendencies, mild or exaggerated, normal and harmless or abnormal in outlet, are deeply seated in human nature. It could have been this kind of incentive which led to the making of our particular record.

[1] Garrick Mallery, in 10th Annual Report, Bureau of American Ethnology, 1888–9, p. 87.

[2] See heading "Sinaitic Inscriptions" in Biblical encyclopedias; or a summary by the present writer in Publications of the Colonial Society of Massachusetts, Vol. XVIII, p. 268, 1917.

These four are alternative possibilities any one of which might have been the reason leading a person to carve his own name or to have it done for him. All the others in our list will apply to cases in which the name has been carved by some one other than the person to whom it belongs. The first group of them to be considered may all be classed under a desire to deceive, to perpetrate a fraud or practical joke. But the particular reason for it might vary; and it might be attended by a hope that the fraudulent record would be publicly and permanently accepted as genuine or it might be of a more private and temporary character.

(5) The incentive might be a hope for personal profit, through increase in the sales-value of the land where the inscription lies, because of the glamor thrown upon it through its connection with romantic episodes or rare objects regarded as precious. The maker of fraudulent antiques which he sells for profit is of course one of the commonest examples of this type.

(6) The only reason for deception might be a desire for enhancement of personal importance and pride because of ownership or other intimate connection with a place so renowned. Mere ownership of fraudulent objects of the most varied kinds, so long as they are accepted by intimates or visitors (not necessarily by experts) as genuine, may often give rise to this kind of satisfaction.

(7) The desire to manufacture evidence for an ardently held belief is a not uncommon manifestation. It runs through all varieties of practice based upon the idea that "the end justifies the means." Religions have been founded upon, or supported by, false documents and pretended revelations. "The forging of ancient documents and inscriptions to prove some contested or desired point is a well-authenticated matter of

modern history.'"[3] Scientists and other scholars have sometimes reported actually unmade discoveries, or have distorted history, in consequence of this urge. Naturally, they may do it also, not for this reason, but for those previously considered—for personal profit or prominence, or because under a dictatorial society only thus can they gain a livelihood and care for loved ones. But they may be tempted by this more unselfish passion to defend a truth. In our particular case, if this had been the motive, the aim evidently would have been to settle the popularly appealing and disputed problem as to the location of Vinland.

(8) The inscription could have been the result of pure malicious delight in deception, with no possible gain or discoverable satisfaction to the perpetrator except that of secretly gloating over his success in fooling a gullible public, or that of gaining repute as a successful practical joker in case he later discloses the truth. This is a motive that is surprisingly often influential. There are numberless instances of such apparently purposeless hoaxes on record.[4] Examples of them seem to be furnished by the unaccountably numerous fraudulent inscriptions and antiquarian relics turned up in America, whose fabricators, so far as known, never profited by their deceptions;[5] and by the inscribed implements and pottery unearthed at Glozel in France in 1924, which seemed at first to prove that men of the stone age developed the first linear alphabet some ten to twenty thousand years ago, but which have since been declared by scientific committees of investigation to be recent frauds.

(9) Closely akin to the last-named motives, but differing in its psychological character, is private and temporary, as contrasted with public and permanent, hoaxing. It may take the form of a practical joke with serious consequences, or it may be the result of a delight in entirely innocent mystification, in having fun through the temporary puzzlement of family or friends. The amateur prestidigitator is moved by this widely influential impulse. Apparently the great wave of modern spiritualism started with a similar innocent attempt on the part of the Fox sisters to mystify the members of their family, with such unexpected success that it became impossible for them to acknowledge their own responsibility for the phenomena until many years later, when it was too late for the confession to arrest the progress of the cult which had its origin in their childish pranks. It is easy to find printed accounts of examples of this not uncommon practice. Ghost pranks not infrequently have this nucleus, and many other types of practical joke. One of the most extraordinary cases on record is the "colossal scientific hoax" of which Dr. J. B. A. Beringer, of Wurzburg, was the victim. Knowing his peculiar views about the nature of fossils, his colleagues and friends prepared a large number of ingenious fabrications of clay, including incredible fantastic shapes of insects and

[3] R. V. D. Magoffin and Emily C. Davis, "The Romance of Archeology," p. 152, 1929.

[4] See P. T. Barnum, "The Humbugs of the World," 1866; J. A. Farrer, "Literary Forgeries," 1907; D. G. Brinton on "The Curious Hoax of the Taensa Language," in Essays of an Americanist, 1890. In the Report cited above, on page 759 Mallery recognizes this motive of "amusement derived from hoaxing" or of "simple mischief"; and speaks also of "craving for personal notoriety" (our No. 6), and of "schemes to increase the marketable value of land" or to sell the fraudulent articles (our No. 5).

[5] A brief survey of some of them is given by M. M. Quaife, in *New England Quarterly*, 1934, Vol. VII, pp. 638*ff*; and another by E. B. Delabarre, "Dighton Rock," 1928, Chap. XVI. The long puzzling "Grave Creek Tablet" has been deciphered, according to *Science News-Letter*, May 24, 1930, as being written in ordinary letters purposely distorted almost beyond recognition, and reading: "Bil Stumps Stone Oct 14 1838."

animals, and tablets on which were geometrical figures and inscriptions in Hebrew and Arabic. These they buried in the ground for Beringer to dig out. The learned professor published a sumptuous book in 1726, in which he used these remarkable discoveries to support his claim that all fossils are capricious fabrications of God, implanted in the earth for some inscrutable reason, whether for his own pleasure or to test the faith of men. When the fraud was exposed, it is said that Beringer died of a broken heart.[6]

Our last five cases have dealt with different types of incentives that might result in deliberate fraud. That they do not form the only alternative to the four earlier cases, in all of which the inscriber himself is assumed to have recorded his own name, we are now about to establish.

(10) Desire to make a purely scientific experiment, by producing a mysterious inscription and seeing to it that it gets discovered, aiming only to learn whether the puzzle can be solved and how the scientists go to work to accomplish it. Perhaps there are no sure examples of the use of such a method, but it must be listed as among the possibilities.

(11) Idle amusement; engaging in an interesting occupation to "while away" a time of leisure or of waiting. This is a natural impulse in active men, and it need not be complicated by any thought of whether the work will ever be seen by other persons, or what impressions it may make upon them. Given some one having a keen interest in the Norse discoveries, present on Noman's Land for a day or longer for any reason whatever, with nothing else to do for a time, uneasy to be doing something to keep himself occupied, one thing that might well have appealed to him could have been the carving of this inscription. He might have been waiting, for instance, for companions otherwise engaged to be ready to go home with him; or for favorable tides or times for fishing or for shooting game; or during intervals between times when he had regular duties to perform, such as engaging in construction work for the owner of the island or such as making surveys or taking tidal or other observations for the government; or he might have sought merely for some interesting occupation while he stopped at the island for several hours as an incident in a sailing trip, possibly by himself alone. Under any of such circumstances, the preference of a great many of us would be to be occupied in some active way rather than to pass the hours in idleness. The time required for making this inscription need not have been longer than a fairly long mid-day when the tide was low and the sea was calm. Such a motive as this was responsible for certain inscriptions on the coast of Maine, which James Phinney Baxter reports as having been made by "boys at play"; and, in the opinion of many authorities, for many of the inscriptions made on rocks by Indians. Grown modern men might enjoy a similar occupation.

(12) A playful impulse to act out the story of the Norse voyages, in the course of which, among other scenes enacted, might be one in which the hero carves such an inscription as he thinks might have been appropriate if Leif had actually done the same thing when he was here. Even grown men, as well as children, sometimes delight in such games. This is one of the possibilities that is worthy of consideration. Children love to play pirates, explorers, Indians; and adults who are fond of children often love to join them. With no children participating to give them an excuse, grown men still carry on similar pre-

6 L. A. Gausman, "The Figured Stones of Wurzburg," in SCIENTIFIC MONTHLY, 21: 515, 1925.

tenses among themselves in their hours of recreation. The members of one of the earliest week-end country camps in the picturesque wilds of southerly Rhode Island constructed a "Druid's Stone Circle" in which to hold ceremonious meetings. In their numerous fraternal organizations, men often call themselves "Red Men," "Knights" and other heroic figures. They clothe themselves in imposing regalia, adopt high-sounding names for their officers, conduct mysterious rites and initiations and guard deep secrets with utmost care.

Play, pretense, pageantry, dramatization—these have strong appeal throughout life for a large proportion of people. When the more serious concerns of life are laid aside, they are enjoyed in widely varying forms on appropriate occasions. Such might conceivably have been the motive for our inscription. Rafn's belief that Vinland was located in this region became known here in 1837, and ever since there have been numerous people fascinated by the idea that the Northmen discovered these shores. Many summer visitors to Martha's Vineyard and other near-by places have certainly shared in this enthusiasm, and some of them surely have possessed an easily acquired knowledge of the forms of runic letters. Many of these visitors hire boats for fishing excursions or to enjoy a day's sailing. At any time since 1837 some such party may have sailed over to Noman's Land and, in a holiday spirit of fun, play and adventure, may have amused themselves by dramatically reenacting Leif's voyage of discovery. They might have made it realistic by pretending that they were Leif himself and his companions, and have carved such an inscription as they would like to have had him leave behind. We can easily imagine some such incident, innocent of any thought of deception or of mystifying those who might later see the rock.

(13) If we knew nothing of the subsequent history of the person whose name we find thus engraved, it might be a sepulchral monument erected by his companions. We do happen to know that this can not be true in this particular case. Yet it may well be included as something to suspect in case of unexplained inscriptions of this type.

(14) The urge to erect memorials to great events and heroes of the past. The world is full of the most varied forms of the working of this urge. They include not only monuments and inscriptions, but memorial days. Examples closely pertinent to our inquiry are the statues to Leif Eriksson in Boston and to Massasoit at Plymouth, and the boulder dedicated to King Philip on the summit of Mount Hope in Rhode Island.

But there are private as well as public memorials of this sort, the result sometimes of a passing impulse, without intention that they should involve permanent and public recognition. There are two examples of this sort in Rhode Island. One is a rock inscribed "To the Memory of Wawaloam, Wife of Miantinomi, 1661," on a private estate in Exeter. The other is a boulder near the foot of Mount Hope, inscribed in Cherokee characters and Wampanoag words to the memory of "Great Metacomet, Chief Sachem," and executed probably about 1834 by a half-breed Cherokee who had a Wampanoag wife.

Our rock on Noman's Land never was the scene of a public tribute. But it might well be a private memorial, the expression of some one's genuine admiration for the bold explorer whose name it bears, unattended by any suspicion of a desire to deceive any one. In such case, no matter when it was done, it would be unjust to call it a fraud or fake. This is the motive which one writer, attributing it to an explorer of the sixteenth century, believes to have been responsible for our inscription.

But even so, it does not by itself help to settle the time when the work was done. The author might have been some member of one of the Norse expeditions following that of Leif; or an explorer around 1500 or 1600; or, just as well, some one within the last one hundred years.

(15) The possibility of a mixture of these motives is not to be lost sight of. Nor must we forget that some other motive that has not occurred to us may have been the influential one. Two recent writers of crime fiction have made their detectives say: "In almost every case there may be motives so deeply hidden that the most skilled investigators would never discover them"; and "Until psychiatry learns to take into account all the quirks of human motive, crime detection will remain an infant science." We are not concerned here with any implication of crime. But these testimonies to the existence of undiscoverable motives are very pertinent to our problem. There are many alternatives to a "hoax" explanation, if our inscription was not the work of Leif Eriksson himself. It is no part of our purpose to decide the question about which one of them was actually the effective one. Our only aim has been to survey the entire range of psychological possibilities. Yet, having stated already that it is the present writer's belief that the inscription is recent, it may not be without interest to add that he thinks it probable that the motive for it was that which we have numbered 14 in combination with the one numbered 11: a genuine private tribute, at a time of leisure which the author of the work, filled with enthusiasm for the old Norse heroes, preferred to fill in with an active and interesting occupation. The reader is asked, however, to forget that, to assume that there are no indications about when or by whom it was done, and then to recognize the entire list of motives as applicable.

If we should broaden our inquiry, we would find it necessary to extend our list indefinitely. To keep it within bounds that might permit a reasonably exhaustive survey of possibilities, we have limited our task to consideration of a single type, especially of a single stone with particular inscription whose origin and date are open to legitimate controversy. We are not now tempted to cover the entire field of motives for making other inscriptions with similar thoroughness. It will help to give a desirable perspective and setting to our limited problem, however, if we enumerate without exhaustiveness some motives that must have been the occasions for other types of petroglyphs.

On New England rocks, the writer has found Indian carvings that almost beyond question were meaningless haphazard scribblings, the product of an impulse to be active anyhow, as some people slash at shrubbery in passing; further encouraged, no doubt, by finding that their artistic efforts aroused the interest and admiration of watching companions. In some cases, probably, such childish scribblings might be the result of an endeavor to imitate, without knowing how, the white man's marvelous art of writing. In other cases, ornamental and geometrical designs are carved, still without meaning, but satisfying an urge for more pleasing artistic expression and eliciting greater applause from the onlookers. The wide-spread urge to make crude pictures of familiar objects, men, animals and trees, is also evident, again due to both motives and still having no wider meaning. Beyond this it is possible, but never certain, that attempts are made to record individual and tribal adventures; they could never be read as such without instruction from the individual recorder, or similar sure clues. Some series of marks might well be arbitrary mnemonic aids to remembering the succession of words in a song, or the stanzas of a magic formula that was

believed to aid, for instance, in securing game or other desired ends; but again, to be sure of this, we would need to have outside information of some sort not often or easily acquired. In all this, as yet, there is no true symbolism. Yet this gets reached at last, in this New England region, in a few cases under influence of contact with Europeans and Colonists. There are a few fairly surely identifiable individual signatures in the form of such "marks" as Indians signed to deeds; or of tribal emblems; and uncertainly of some simple designs that may have had a religious significance. There are known only one gravestone, one rock and one bannerstone in all this territory which appear to give evidence that Indians, after long contact with white men, had begun to evolve an ideographic or syllabic system of writing that was used in one case to mark a grave, in another to pay a tribute of admiration for a hero of the past, and in the third to indicate personal possession, expressed in definite words. There may have been other types of marks, and other ideas expressed, but we have no means of being sure of this. Even pictographic writings, commonly supposed to have been characteristic of Indians, are wanting in New England except in case of a very few possible indications of directions for travel, or some very few other indecipherable and uninterpretable cases. Other inscriptions in New England, not due to Indians, fall within the classes of motives already recognized, except one. Religious exhortation to lead a more pious life has been the motive for both painted and carved writings, in English, on some Rhode Island rocks. Similarly, instruction in the mysteries of an occult religion was suspected, mistakenly, by Moreau de Dammartin as having been the aim of Egyptian priests in carving Dighton Rock.

Many writers attribute carved or painted figures of animals or plastic representations of them, in America and elsewhere, to the belief that thus magic power is gained to secure them as game. In still other cases, more definitely religious ideas are assumed, such as the propitiation of higher powers, or expressions of gratitude to them. In one well-argued case, the carvings are believed to be the record of a Great Adventure performed by daring individuals who braved the dangers from guarding spirits of a difficult descent into deep recesses where salt might be obtained. Those who believe in the authenticity of the Kensington stone in Minnesota and of the Kingiktorsuak inscription in Baffin Land, and many others elsewhere, look upon them as similar records of great adventure.

These last considerations suggest only a few of the motives that may have been causes additional to those mentioned in our own selected single case. Doubtless many more might have been discovered. For the one case, at least, we have attempted to survey the possibilities as exhaustively as we could.

THE NEW ORDER OF THINGS

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As I meditated upon the subject of my address[1] to you to-day, there came to me a vision of that period a few decades ago when I and my companions stood, as you stand now, at the threshold of life, each with our story of the world as it had been handed to us and with our little kit of tools, mental and spiritual, designed for the tasks ahead of us, and fashioned according to the principles of our teachers.

For those who chose the paths of science, the outlook was melancholy indeed, for within the period of our own studentship one of the wise men of our calling, looking into the future and seeing naught but barrenness, had uttered his belief that active science had come to an end—that there was little more to do but repeat the investigations of the past with new, but not over-exciting refinements, as one would play and replay the music of the old masters with ever a little more attention to refinement and detail.

The science of electrical engineering had become established upon firm foundations. Public buildings were lighted by electricity, and certain wealthy people had even gone to the extravagance of installing this expensive method of illumination in their houses. Electric street cars went all over the city, but were still a source of wonderment. Even one of my teachers who had taught me about these things ceased not to marvel that the influence responsible for carrying the car up the steep hills of the town could travel along a relatively insignificant copper cable.

Not many years earlier, as a boy, I had witnessed a truly remarkable phenomenon of a hundred or so automobiles, which under the guidance of certain hardy and venturesome individuals had set out to make the journey of fifty miles under their own power from London to Brighton. The few which arrived seemed to be on their last legs as a result of the ordeal. Clattering along with many and diverse noises, explosions, squeaks and rattles, they had demonstrated that the thing could be done. I often think of the consternation which would have been produced in the mind of some citizen of sixty years ago if he could have been transplanted for a moment in time so as to catch a glimpse of a modern automobile. I can imagine his returning to his own epoch and telling the story to his friends in such words as these:

> I have had a most disturbing experience. I met a man—he assuredly must be a madman—who showed me a curiously shaped thing which was somewhat like a wagon of no small weight, but instead of having strong substantial iron tires, the thing stood on four rubber tubes blown out with air. It was a most ridiculous contraption because, obviously, the rubber tubes must wear out before the thing could travel a mile. But the most fantastic feature of this contrivance concerns the manner of its propulsion. We all know that gasoline vapor and air form a most dangerous mixture, which, when ignited with a spark, explodes with great violence. Well, this strange vehicle was driven by a series of such explosions which took place within its interior and were somehow arranged so that they did not blow the machine to pieces. I asked the inventor of the vehicle how the occupants could tolerate the terrific bombardment and shocks which must be incidental to its propulsion. When I tell you that he informed me that the shocks and noises were inappreciable, you can judge for yourselves as to his sanity, the more so since no sane person would build a contraption based on principles which at the best must result in the whole thing shaking to pieces in no time at all.

[1] Delivered on June 10 at the commencement of the University of Florida.

But outstanding as are the changes which have resulted from the development of engineering skill and from the utilization of the discoveries of the last century in the field of engineering and electricity, they are as nothing compared with those changes which have taken place in our mental vision of that physically invisible universe of the atomic kingdom whose laws control, ultimately, all the phenomena which present themselves to us in our everyday affairs of life.

There are periods in the progress of science when nature seems to present a great barrier to further vision. The phenomena which are the subjects of our interest seem to divide themselves into two classes, those concerning which we know everything that it seems worth while to know and those of which there seems no hope that we can know any more. Forty years ago physical science found itself in this state. The coarse-grained laws of matter had been well fathomed. We had evidence that matter was composed ultimately of very small things, atoms and molecules; but it seemed as though, rich as might be the story of these small things, it must necessarily be a story hidden from us forever. And so, the sage of our calling, whom I have cited earlier, offered his famous dictum whose meaning was that discovery was ended and that science was dead.

It was true that we were compelled by logical argument to believe that even coarse-grained phenomena presented by matter in bulk were somehow or other determined by the properties of the atoms of which the matter was composed, but there seemed little hope of extracting through an examination of those crude phenomena anything like a complete story of the inner workings of the atom. We were like the ancient Britons ruled by Rome. That which happened to them was determined in some way by the structure and government of Rome, but most of the richness of Rome was bound up in itself and had but little bearing upon the external empire. That empire felt the power of Rome only as an incidental side-activity of that power. Then, science was startled by the discovery of the electron, a fundamental element of the structure of the atom. This was a great encouragement. It was as though the barbarians had found that Caesar lived not always in Rome, but occasionally went abroad. Might it not even be possible to kidnap this Caesar of the atom and make him perform for us barbarians that we might learn of what metal he is made? Then before long, tempted forth by the activities, of whose drama the barbarians had made Caesar the chief actor, came Caesar's consort, the proton, to dance in the revels of a life free from a mere atomic existence. Free from the monotony of this existence, Caesar found new powers of which he had never known before. He could be made to run with great speed, and by his own individual energy to cause light to flash forth from that which he struck. This Caesar of the atom, the electron, could, in fact, eject ultra-violet light from metals with which it collided. When excited to great energy it could create x-rays in crashing through the atoms in which it had formerly reigned as king with little to do but carry out a conventional routine.

For more than a decade, physicists hoped to have found in the electron and the proton the two fundamental bricks out of which all the architecture of nature was fashioned. Having found the bricks, man was encouraged to see what kind of structures could be built of them. From his investigations of the properties of these bricks he had come to some conclusions as to their nature. The electron was a thing so small that if we should magnify its diameter so that it attained the size of a piece of small lead shot, that piece of lead shot would, on the same scale of magnification, become larger than the sun. The mass of the electron was so small that if we should

magnify all masses so that the electron attained a mass of one tenth of an ounce, that one tenth of an ounce would, on the same scale of magnification, become as heavy as the earth. The proton was found to be two thousand times heavier, but two thousand times smaller than the electron, so that if we should magnify such a proton to the size of a pin's head, that pin's head would, on the same scale of magnification, attain a diameter equal to the diameter of the earth's orbit around the sun.

It is characteristic of mankind to try to fashion the new upon the model of the old; and so in building pictures of the atom out of electrons and protons, the hope was to make the mechanisms in those pictures something like the mechanisms of everyday experience. The physicist would have liked to picture the atom as a kind of complicated watch or a special kind of dynamo or as a little solar system or a conglomeration of springs, something, in fact, with which he was already familiar; and he hoped to extract out of the models of this kind characteristics which could represent the atom.

One of the most characteristic features of matter is exhibited when, in a gaseous form at reduced pressure, it is caused to emit light under the influence of an electric discharge sent through it. Under such conditions it emits light of definite colors characteristic of the gas. For many years, science had recognized the fact that the secret of the explanation of these colors was, somehow or other, to be sought in the nature of the atomic mechanism producing the colors. The first thought was that the electrons in the atom were constrained to move in complicated vibratory motion when excited, like a lot of balls connected by springs, and that the motions communicated themselves to the surrounding medium, the ether, which was supposed to permeate all space and serve as the means of transmitting light and heat from the sun and stars. The different kinds of motion of the atomic springs were supposed to correspond to the different colors of light emitted by the atoms. Alas! it was soon found that this kind of picture would not fit the facts, and the trouble was that nothing like it could be made to fit the facts. All sorts of modifications of the details of these mechanisms were imagined, but there was something in all of them which ran just contrary to what was required to correspond to the observations. The unfortunate thing was that the characteristics of these models which were most unsatisfactory for the purpose in hand were just those characteristics which made them most pleasing to the mind as intuitively understandable models. It is as though we tried to understand certain of the features concerned with the building of a bridge by thinking of the bridge as built by artists. Perhaps the features concerned are those having to do with the letting of contracts and the administration of matters pertaining to construction. We find it difficult to picture the artists as doing these things; and if we modify the characteristics of the individuals so far as to make them fit the duties required of them, we find we can no longer think of them as artists. If one is sufficiently sophisticated he can claim that an artist can also be a good executive and business man. I do not deny it, but, if the picture of an artist which you have formed in your mind is that of a being to whom these activities are foreign, you can not retain these characteristics in the picture and yet have it satisfying to you. At least, you can not do this unless you decide not to think too much.

When it became quite clear that no kind of model built on the lines of concepts which were familiar to us could be a satisfactory representative of the atom, we reluctantly accommodated ourselves to a new philosophy in the theory of the atom devised by Niels Bohr. In this

theory there was a compromise. The atom was half model and half something else. We came to think of the atom as a little planetary system. At the center was a nucleus containing all the positive electricity of the atom and most of its mass; and around this nucleus electrons revolved according to the same laws as those which govern the motions of planets in their journeys around the sun. But now it was necessary to suppose that this atom had certain additional characteristics which the ordinary laws of a planetary system would not require; and, worse still, it was necessary to suppose that the atom would do certain things which a strict interpretation of the planetary laws would really deny. Only certain of the orbits which would be permitted by the planetary laws were allowed in our picture and no reason was given for the exclusion of the others. Then it was supposed that the electrons could jump from one possible orbit to another and emit light in the process; but no reason for this performance was given and no detailed story of what happened during the performance was told.

When the man of science tries to speak of these things to the layman, it is difficult to do so without conveying the impression that he, the man of science, is ultimately a hopeless lunatic building castles in the sky. In order to avoid complete surrender to this accusation I must beg you to believe that in this theory of Bohr there is something else. There is a foundation of a consistent set of rules or laws for the behavior of the atom which contain in themselves the power to predict much that occurs. There are in fact two things. There are the system of rules and the model. The model, it must be admittted, is terribly unsatisfactory. The more we think of it, the worse it is; but the rules which go with it are perfectly definite.

One may well argue: What is the use of seeking an explanation of the behavior of the atom by setting up a set of rules which are chosen for no other reason than that they harmonize the facts, and which contain no other reason for their existence? The point here is that the man of science tries to reduce the number of his rules to a minimum. The facts of nature and those associated with the atom in particular are many. The man of science seeks some way in which by stating a few principles he can make those principles the keynote of all the rest. Then he can understand all the rest *in terms of those principles,* even though he may not understand the reason for the principles.

The man of science seeks a way in which, by postulating a few things, he can deduce as their consequence many things which are found true to nature. The classical example of this method is found in Newton's formulation of the law of gravitation. I will not remind you of what the law of gravitation is, further than to state that in it Newton stated one thing about the motion of the heavenly bodies, and from that one thing it was possible to deduce all the consequences of classical astronomy. It was possible to calculate the shapes of the orbits of the planets, the time of occurrence of eclipses, the time of return of comets, the relation between the periods of revolution of the planets around the sun and their distances from the sun. These and a hundred other things it was possible to calculate from that one statement embodied in the law of Newton.

When I strike this desk, I produce very complicated vibrations in it. Probably no mathematician living could calculate all the details of those vibrations because of their complexity; yet I feel that I understand those vibrations, because I believe that nothing but complexity of mathematical calculation exists between the complete story of them and one or two very simple laws concerning the way in which the motion and the shape of a little cube of wood respond to forces applied to it. It may sound

rather strange to say that the physicist likes to take a simple thing and make it complicated. Yet that, indeed, is one of his main activities. He likes to grow out of simple things a complexity which corresponds to the complexities which he observes in nature. Then he can feel that his understanding of the complex is reflected back to his understanding or acceptance of the simple.

And so the main feature of this theory of Bohr was that in terms of a few simple assumptions much of the story of what was observed in the doings of the atom could be deduced. What remained as a model in that theory was a sort of half-hearted attempt to seek comfort in believing the few simple things by hoping that some kind of reason for them could be provided by the model. The irony of the situation was that the parts of the model which had the greatest pictorial significance were just those which played no part in the story of the atom's activities. It is as though in trying to represent the characteristics of a certain animal, I hit upon the idea that perhaps he was an elephant, but found that in order to explain his activities it was necessary to assume that his trunk was used only for purposes of wagging, while his tail was used for carrying things about, that his ears were not used for hearing, but for the absorption of food. It is doubtful whether I should be justified in deriving much comfort from the thought that this animal was an elephant.

I have frequently meditated upon what I have sometimes called the "irrelevance of the obvious." I picture a situation where I set a problem to a school boy. The problem is to the effect that a ball is thrown upwards with a certain speed, and I ask the boy to calculate how long it will take for the ball to attain a certain altitude. He comes back and complains that I have not given him enough information. I ask him what further information he desires. He tells me he would like to know the color of the ball. I tell him that the color does not matter. But he may not like that, because some of the reality of the ball has vanished from his vision with the color. He asks me for the weight of the ball, and I tell him that doesn't matter either; and I add to his troubles by telling him that I will withdraw even my remark that it was a ball and leave its shape indefinite. Then, if he is over-materialistically minded, he will explode entirely and demand to know how he is to work out any problem about the body if I won't tell him anything about it. There is nothing left for him to think about, and he may well claim that it is difficult for the human mind to think at all unless it has something to think about. Well, to please him, I tell him the body is red, weighs ten pounds and is really a nice round ball. Now he is happy. He takes his paper and pencil, draws the round ball, puts a 10 inside it, paints it red in his mind's eye, and works out the problem. When he brings me the result, I inquire at what point the redness of the ball came into his calculations. He looks through them and finds it didn't come in at all. The result would have been the same for a blue ball. Then I ask him where the 10 pounds came in. He looks again and finds he did not use it; or, if he did, it cancelled out, so that the result would have been the same for a fifty-pound ball. Finally, I ask him where the roundness came in, and he finds he did not use that at all. So I say to him, "Don't ask me a lot of unnecessary things again." But I think I hear you sympathizing with the poor student. "What harm," you say, "did the redness of the ball do? Why did he sin in thinking it was 10 pounds in weight and that it was round, if after all these things did not matter?" Well, I agree; in this particular case the redness did no harm. But I suspect that if I let the student think the ball is red, he will come to me some day with some ideas founded purely upon the redness of the ball. He will be

troubled because he will want some other ball to do the same sort of thing that this ball did and will be unable to satisfy himself because, perchance, the second ball is blue. Then, I shall have to go to the trouble of raking up past history to show that the redness did not matter in the former case; but, if he has enjoyed the vision of redness for a long time, his whole mental equilibrium may be destroyed if I take it away, and he may be quite unable to think at all without it.

An archdeacon has been defined as one who performs archdeaconal functions. Sometimes we laugh at that definition; but, provided that the functions are expressed explicitly, it is a very good definition—a much better definition, for example, than one which defines the individual in question as one who wears gaiters and a top hat of rather ostentatious shape. It is true that the gaiters and the top hat are the most immediately obvious features of the archdeacon, but one who riveted his attention on these appendages as the most fundamental attributes of an archdeacon might be at a loss to understand the significance of the individual, if for some reason he were without them, in spite of the fact that he might be just as good an archdeacon. The obvious part of the archdeacon is irrelevant to his true functions. And, so in science, we encounter many instances where we choose to think of things mainly in terms of their activities, and we are loth to add to them appendages which may hinder or complicate these activities.

Thus it appeared that all that was gained in any attempt to hang on to something like a model for the atom was to hang on to something which played no part in anything which really mattered, something which was cumbersome, a continual source of trouble and whose only use was to provide an illusion of comfort based upon some idea of reality which it might be supposed to afford.

In the next stage, which has developed during the last ten years, physicists have been content to make a complete break with the idea of models and to formulate the principles of atomic activities in purely formal terms. The rules which govern the behavior of the atoms are more like the rules of a game. We do not hope to see why they should be so. They, themselves, are the "why" of everything, and there is no "why" for them. The desire for a model was simply the unconscious desire to understand the unknown by analogy with the known. If we wish for an analogy to describe the modern view of the atom, it is not in terms of models that we must seek it. The characteristics of individuals would give, I think, a better analogue than those of machines.

In ancient times, when unaccountable things happened, people attributed them to the gods. If thunderbolts fell, the gods were angry. If all was fair, the gods were pleased. Of course it was necessary to come beforehand to some agreement as to the dispositions of the gods. Now in the modern theory of atomic structure, we may liken the atom to the gods. We have come to realize that the atom can exist in a number of different states of energy. We may liken these states to different states of the gods: the gods in peace, the gods at war, the gods hunting, and so forth. Now the mathematician has found out how to calculate, for the atom, a quantity analogous to what we may call the degree of amiability of disposition of the gods in these various states.

In any one of these states of the atom there is a quantity which we may call the degree of anger of the atom, and determined by the external conditions to which the atom is subjected. The atom has the characteristic of being angry in a lot of different ways at once. It is as though the gods had righteous anger, malicious anger, war-like anger, and so on. When the atom is angry, it may do one of the various acts which it is capable

of doing. It may emit a splash of energy associated with one kind of light or a splash associated with an x-ray or it may hurl out an electron. If, in general, the atom is angry in a lot of different ways at once, then the chance that it may do the various acts associated with the various kinds of anger is to be regarded as proportional to the intensity of the appropriate kind of anger. It will be observed that there is no certainty that the atom will do any one particular thing. There is merely a chance, a chance which is proportional to the kind of anger associated with the event. The atom is like a cat. You may torment it and it may do nothing, but the chance of getting scratched is proportional to the annoyance of the cat. There is no attempt to make a story of just how the atom operates when it "strikes." Indeed, the physicist has come to see that there is very much less content to that question than might be supposed.

But, you may say, is this not a terribly complicated way of talking about atomic phenomena? No, it is ultimately more simple. In other words, we can get a better correlation between the various actions of the atom by referring them to laws about what we may call the "temperament" of the atom than by seeking an explanation in terms of springs and weights. After all, that is not surprising. Who would attempt to decide what an operatic prima donna, or, for that matter, any woman, would do under given circumstances, by an appeal to the laws of springs, weights and machinery? The fundamental thing is that she is angry, for instance. That is the starting point, and there is no going back of that fact. Everything is accounted for in terms of the anger, but there may be no accounting for the anger.

The modern view of atomic structure which I have sketched very incompletely possesses an applicability and meaning over a much wider range of phenomena than was the case with the older theories. It is true that we do not *see* just how things should go in certain cases, but the underlying general principles seem to be there. The story of the atom's light emission, of the conduction of electricity in metals, of the photoelectric effect, of x-ray phenomena, of electric fields necessary to pull electrons out of metals under different conditions—all these become told in terms of a common language; and, while the story of the nucleus and of atom-building processes has not been completely told, a good beginning has been made.

One of the chief revolutions in thought brought about by the new philosophy in physics is the denial of the principle of determinism. If the positions and motions of the sun and planets were given at some instant, then, through the operation of the law of gravitation it is possible to calculate their positions and motions for all time. We can calculate what the solar system will look like a million years hence as easily as we can calculate what it will look like to-morrow. The future history of the heavenly bodies is irrevocably bound up with the present.

Now, altogether the laws which govern the more detailed activities of matter in general and of atoms in particular may be expected to be far more complicated than those which govern the solar system, there was always at the back of our minds the thought that if we knew what those laws were we could calculate, with absolute precision, the story of the future in terms of that of the past. Driven to its logical conclusion, this would mean that the act of my giving this address to-day is intimately bound up with and in a sense a direct consequence of what happened in the reign of Julius Caesar. In a sense, Julius Caesar, or some of his contemporaries, was subconsciously aware of the necessity of this address, and somehow or other managed through many generations to convey the idea to President Tigert. At first I am overwhelmed with the tremendous responsi-

bility placed upon me by Julius Caesar and his contemporaries in arranging, so far ahead, that I should speak to you today. But on second thought I cease to worry, for I realize that after all the responsibility is not mine and that really the address itself was, somehow or other, subconsciously written, or at any rate, determined, at the time of Caesar. The paradoxes in these matters have worried the man of science for many years. He hated the implications involved in such examples as that I have cited in connection with Julius Caesar and my address. If he did not admit them his whole scheme of physical law seemed to break down. And yet he was frightened from the opposite angle, when he thought of free will, so he went to church on Sundays and believed in free will, and during the remainder of the week he sought to show by his experiments and theories that everything was predetermined. While my own view as to this question of predetermination versus free will, etc., holds that it is rather a tempest in a teapot, and maintains that in the last analysis there is not as much difference between them as is usually supposed, the limited space of this address will not suffice to give the reasons for this attitude. The point which is to be emphasized here, however, is that we have come to realize in physics that an expression of the laws of nature in such a form that we say such and such a thing has only a certain chance of happening, rather than a certainty of happening, is not such an expression of incompleteness of knowledge as we formerly thought. We can have the laws in this form as a practical basis for unifying our experiments; and the old-time desire for something which seemed more "complete" is rather analogous to the desire of one who asks the question. "If an elephant could solve mathematical equations, would he also be a good musician?"

Many who have grown old in the mechanistic vision of nature view with regret any departure from it. They hope and hope that some day one will find once more a way to view the atom as mechanistic. I, for one, would be willing to join in the labor of striving continually for this goal but for one thing. That thing concerns the fundamentality of the goal itself. The more critically we examine the matter, the more do we find that there is really nothing in the mechanistic picture as a starting point which gives it a right to pose as a more fundamental starting point than any other. The mechanistic picture is pleasing to us because we are familiar with it, and this familiarity gives a certain illusion of fundamental contentment in it, as though we felt that once we could get back to a mechanism we would have arrived at an explanation which itself called for no explanation. There was a feeling that every other starting point was a makeshift, was artificial and called for a reason, but that the mechanistic starting point called for no prior reason. Now I have no quarrel with the idea that the mechanistic starting point calls for no prior reason. My quarrel is with the claim that it is unique in this matter. My quarrel is with the idea which forbids any other starting point to claim the same thing. I am aware that a superficial view of the mechanistic picture seems to give it a substantiality, a reality, superior to other pictures. Had I the time, however, I could take any one of these pictures which are especially appealing to you and if you should point out to me the things in it which gave it the semblance of fundamental reality, I could contrive to make you extremely uncomfortable in your reasons for contentment.

When one is confronted with a situation such as one meets in devising theories of the atom, one is apt to be worried continually by the groans of a specter which is always in attendance when anything new is under consideration. The specter's name is "Common Sense." He

is usually regarded as a most respectable being. He manages to preserve a high reputation for profundity by a dignified avoidance of saying exactly who or what he is. Now, I will not deny that "Common Sense" has his merits. In his proper domain he is a counselor of priceless value; and it is because he justly inspires such confidence in that domain that he becomes the most dangerous of deceivers of those who seek his guidance outside of it. For "Common Sense" seeks to pin all thoughts of the new to the fabric of the old, and so, ofttimes, he distorts the meaning of the new by destroying that form which was inherent in it in its own right, and for no purpose other than to fit it to a pattern with which it has no harmony. The result is a bizarre and shapeless thing out of harmony with the form into which it has been forced and out of harmony with the form which was its own. Common sense in natural philosophy repatterns itself from age to age. At each stage of its development it seeks to generalize the ideas born of the experience of the immediate past and to weld them into bonds which sometimes restrain the future. Thus, the breeders of error in the epoch to come are sometimes the truths of the days which have gone.

It was the common sense of the ancients which made them see the sun as carried around the earth by angels. It was the common sense of the Egyptians which made them see the universe as a box with a river running around the outer edge, the river carrying a boat and the boat carrying the sun. It was common sense which, in the time of Kepler, saw the sun endowed with spokes to which were attached the planets and which, through the rotation of the sun, drove the planets around in their orbits. It was the common sense of the astronomers of the time of Galileo which made his discovery of the satellites of Jupiter seem nonsense and his discovery of the laws of falling bodies contrary to reason.

And so common sense to-day groans at the modern atom. And yet in what a curious light it places itself by so groaning. For, to explain the actions of matter in bulk we have been driven to the thoughts of atoms and molecules. Then we have felt the necessity to go further and formulate a set of laws for these atoms which would account for the behavior expected of them. By a strange kink in the psychology of mankind, common sense has held us to a hope that those laws would partake of the same nature as those for matter in bulk. It is as though having studied cities, and having come to the discovery that they were composed of buildings, which in turn were composed of bricks, we had then begun to meditate upon the bricks and had sought to see some way in which they could be regarded as composed of houses put together in some kind of way suitable for the explanation of their tenacity and strength. Common sense is a good servant, but a bad master. So beware how you glory too much in good old "horse sense"; for, in the last analysis, "horse sense" is in all verity the kind of sense that a horse has.

Quite apart from the philosophical principles involved in the theory of the atom, the last two or three decades have brought to light a startling picture of the way things happen in the atomic world. One of the first things which surprises us in examining this picture is the fact that the atomic activities which constitute the chief phenomena of our interest are activities whose occurrence is so very rare from the point of view of the individual atom that they would constitute miracles to an intelligent inhabitant of an atom, if we could imagine such a being. In every cubic inch of the air which you breathe there are about ten thousand molecules which are in a peculiar state. They have lost an electron and are consequently charged to the extent of one proton. To us there is no miracle about this matter. I could bring

into this room a comparatively small piece of apparatus with which, in five minutes, I could measure the number of these peculiar molecules. Yet, think what a strange phenomenon we have here when viewed from the standpoint of the molecules themselves, for that cubic inch of air contains about five hundred million million million molecules, and only ten thousand of them have lost an electron. In other words, out of every fifty thousand million million molecules only one has lost an electron. If a molecule were to go about saying that it had once seen one of its brothers which had lost an electron, the story would be less likely to be believed than would the assertion by some person that he had seen a man with two heads, if he were the only person who had seen such a monstrosity during the whole history of the human race. Indeed, the assertion in question would have a much better chance of being believed than would the story told by the molecule which had lost an electron. For a molecule would, on the average, have to meet fifty thousand million million other molecules before finding one that had lost an electron; and if you could have lived long enough to have met all the people who have ever lived, in your search for the two-headed man, you would probably have met less than a million million people.

We may view the matter from another angle. The charged molecules in the air attract one another and so are continually coming together and neutralizing one another's charges. It is only because electrons are being continually torn from the molecules of the atmosphere that all the supply of charged molecules does not disappear. An important agency responsible for tearing the electrons from the molecules of the air is the cosmic radiation which comes to us, probably, from outside our atmosphere. In order to account for the maintenance of the observed number of charged molecules in a pure atmosphere it is necessary to suppose that in each cubic inch about twenty or thirty molecules have an electron torn from them each second; and, as a matter of fact, we know that the cosmic radiation is capable of accounting for such a result. But think what an exceedingly rare phenomenon this catastrophe of the loss of an electron is from the point of view of the molecules themselves. It is as rare a catastrophe to the molecules as would be a murder in the realm of mankind if, with the population of the earth at its present value, only one murder were committed on the whole earth in three hundred years.

Most of the outstanding phenomena of modern physics are miracles from the point of view of the atom. The photoelectric effect, which is responsible for the operation of the photoelectric cell, which in turn is responsible for the wireless transmission of pictures, is the ejection of an electron from an atom through the agency of light. We have been accustomed to think of an atom as a little solar system with electrons revolving around a central nucleus. Now in the photoelectric effect, you must think of a light beam shooting into an atom and hurling one of these electrons out of the atom in some such manner as that in which we might suppose a flash of light from the depths of interstellar space to burst into our solar system and hurl the earth into outer darkness. The latter idea is a fantastic one, you will say. True, but much less fantastic than the photoelectric effect would seem to an inhabitant of an atom if there were any inhabitants. For, even if we confine our attention to the atoms (they are atoms of potassium or caesium) which are on the sensitive surface of the photoelectric cell, we shall find about a hundred million million million of such atoms, and even with a strong photoelectric effect any one of these atoms would, on the average, suffer the catastrophe of the ejection of an electron only once in ten million

seconds, *i.e.*, about three times a year. But a year of our time would seem very long from the point of view of the atom. Things happen very rapidly on the atom. In the sense that the year for an electron of the atom is the time taken for that electron to revolve once around the nucleus, one of our years is equal to about thirty thousand million million million atomic years. Thus, from the point of view of the atom's measure of time, an atom of the sensitive surface of the photoelectric cell experiences the catastrophe of the photoelectric effect only three times in thirty thousand million million million years. Such a phenomenon may well be regarded as a miracle.

In an incandescent gas, we have been accustomed to think of the emission of the light as a phenomenon accompanying the fall of an electron from some orbit around the nucleus to another orbit of smaller size, a phenomenon analogous to the fall of an electron from some orbit to some other nearer the sun. Even in the case of a gas which is emitting light copiously, however, the number of atoms of the gas which participate in the light emission at any instant is so small that to the individual atom the phenomenon of light emission must seem as remarkable as the fall of Neptune from its orbit would seem to us. X-rays are produced by the bombardment of the atoms of a certain piece of metal in the x-ray tube by high-speed electrons. Yet even if we should confine our attention to the particular atoms which constitute that particular piece of metal which went into the construction of the x-ray tube, for the atoms, the phenomenon associated with the emission of an x-ray is such a rare one that if you lived on one of the atoms, participating in the pace of life natural to the atom, you would probably be put in an atomic madhouse if you insisted on suggesting that any such phenomenon as the emission of an x-ray had ever occurred.

With what a curious situation are we presented. Here is a set of phenomena which constitute the crucial activities upon which modern science is based. The evidence of these things is all about us—the phenomena themselves are less obscure to us than arguments about atoms and molecules. Even in the realms of nature's spontaneous activities they play a fundamental part. The emission of light goes on everywhere. The photoelectric effect is continually operative in the economy of plant life; and yet, from the point of view of the actual things which are the seat of these phenomena, from the point of view of the atoms, the phenomena themselves are of such rarity that no less drastic a word than "miracle" is fit to describe them. Imagine an inhabitant of an atom looking out upon the external world and seeing a furnace. The phenomenon should surprise him considerably; for he would be unable to explain its activities without invoking phenomena of such a character as would put him in a lunatic asylum if he suggested their possibility. And he would be in the same predicament with regard to most of the interesting things which were happening in the world. As a matter of fact, if he confined his attention to only the phenomena which he would have a reasonable right to expect, he would conclude this world to be a very uninteresting place.

I can well remember the time when of all "boners" which could be pulled by the student of physics in an examination, none was more heinous than one carrying an implication that atoms of matter could be broken up, or divided in any way into their constituent parts. To commit the sin of such an implication was for the poor wretch who was guilty to relegate himself to the realm of the scientifically hopelessly lost. Even the great Lord Kelvin shuddered when responsible men of science began to question the permanence of the atom. "For," said he,

"from the very word atom comes the implication of an indivisible entity."

Only one thought could be deeper in the mire of heresy than that which played in imagination with the permanence of the atoms, and that thought concerned the conversion of one element into another. The transmutation of the elements, the dream of the alchemists of old, was the typical example of wild charlatanism and uncontrolled speculation. To-day we face the accomplishment of this act heretofore regarded as so far outside the realms of possibility. One after another the elements are being broken up through acts under the control of man. They are being converted from one to the other; and, while we have not reached the goal in which atomic transmutation has been realized in such large amount as to have a significant bearing upon the production of elements on a commercial scale, an encouraging beginning has been made. Indeed, already new elements, such as radio sodium, having properties different from those of the elements which nature has given us, are being produced artificially in amounts sufficient to be of use in medical science.

Within the last few years, we have come to a realization that matter itself, formerly thought indestructible, can in actuality disappear, and that when it does so disappear, energy is created in its place. So great is the energy equivalent of even a small quantity of matter that the annihilation of a single drop of water would produce enough energy to supply two hundred horse power for a year. For many years the source of the heat poured out from the stars was one of the most perplexing mysteries of science. Were the story simply that of a hot body cooling, our sun would have run cold almost within historic times. None of the more obviously available sources of heat were adequate to the task required. Now we believe that in the annihilation of matter by the devouring of their own substance the stars find that source of energy to pay to the universe the tax which they must pay continuously in the form of radiation.

It is far beyond the scope of this address to enumerate all the fields of practical utility in which the scientific discoveries of the last thirty years have found place. It is a significant fact that most of the scientific developments which have played vital rôles in the practical affairs of life have arisen from discoveries made in the first instance with no utilitarian end in view. It is not meet, however, that one should seek to excuse the existence of any science or art by pointing out its utilitarian features.

In the matter of utilitarianism I have sometimes meditated upon a supposed conversation between an apostle of utilitarianism and one whom we will call an artist of the art-for-art's-sake type.

"Of what use are those pictures in the Vatican?" asks the utilitarianist. "They do nobody any good and only wasted the time of Michelangelo, who painted them."

"And what kind of creative work would you regard as of use?" asks the artist.

"An example is the development of the steam engine and the automobile," says the utilitarianist.

"But why are these of use?" says the artist.

"Because they enable one to move about faster and get more done," says the utilitarianist.

"But why move about faster and get more done?" replies the artist.

"Because by doing so you create wealth for yourself and others; you save time and are enabled to enjoy more leisure," is the rejoinder.

"And what is the use of money and leisure?" asks the artist. "Is it not rather boresome to have nothing to do?"

"Oh! it is not necessary to do nothing," is the reply. "You can travel and enlarge your mind."

"But," says the artist, "what is the

good of traveling? You only get seasick and very tired."

"Oh!" replies the utilitarianist, "it is a wonderful experience to travel. You can go to the old world and visit all those places of classic renown: Paris, Venice, London."

"But," says the artist, "is that not very disturbing? I hear that many of these places are unsanitary. The food is not what you are accustomed to, and sometimes the people are not over-friendly."

"Those are but small matters," says the utilitarianist. "They are far outweighed by all of the other riches you fall heir to. You can bask in the exhilarating sun of the Alps. You can drink in the beauties of the Mediterranean. You can visit ancient Rome; and when you are there do not fail to see those marvelous pictures painted by Michelangelo in the Vatican."

And so I have wondered if we should be far from the truth if we should maintain the thesis that the only ultimate excuse for the existence of the things utilitarian is that they provide the means whereby we may enjoy the things non-utilitarian.

In the new era which is before us, and upon which you will now enter, mankind is likely to enjoy far more leisure than has been the lot of our forefathers. With the world's work done largely by machines, the day is coming when but a fraction of man's time will be occupied by the necessities of existence. What are we going to do with the remainder? I think it is safe to say that one obtains permanent satisfaction only out of the things on which he has done serious work. You may decide to devote the whole of your life to golf, but unless at some time in your life you work as hard as a navvy to improve yourself in the game, you will soon reach a stage where your enjoyment lags. I would suggest that the very characteristic which determines a good game is that it shall be something at which one can work continually, in which one can continually improve and yet never attain perfection. Following this criterion, golf is a good game. Billiards is a good game. Ping pong is not such a good game, because in a relatively short time a large number of people can go practically as far as it is possible to go in the game, and it has no further richness to stimulate improvement.

The consciousness of improvement is more satisfying than the realization of success. There is no more unhappy being than the man or woman who has attained middle age and has never done any serious work at anything. Such people go to concerts, but know nothing about music, and soon they are sick of concerts. They go to plays, knowing nothing of literature, and they are sick of the theater. By the time they are forty they have exhausted all the superficialities of pleasure and are heartily sick of everything. The only excitement left is an ailment or a grievance. In the years which have passed, this state of affairs has been the potential lot of the wealthy few, and only they have had the problem of leisure before them. In the years ahead of us, however, the leisure problem will be one for all of us. It will be necessary for an individual to work hard in his youth that he may play with satisfaction in his maturity. I vision a day when each of us will have his vocation, and an avocation in which he is not necessarily less proficient than in his vocation. The former is his contribution to the necessities of existence; it is the thing he is paid for. The latter he does as his own master. When this day comes perhaps we shall once more find a world in which there is time to do a thing well.

In this world of turmoil and scientific achievement, where the science of even fifty years ago seems obsolete and primitive in its character, compared with the

science of to-day, it is almost a shock to turn to other fields where time has wrought less changes. Three hundred years ago, the old Italian masters made violins, violoncellos and similar instruments. The general form and character of those instruments is quite obvious, and indeed for five dollars one can buy a violin which looks in its general characteristics very much like a "Strad." But the "Strad" is worth fifty thousand or even a hundred thousand dollars; and there are many musicians who will tell you that it is worth it, and that the value is not a fictitious one based upon the antiquity and rarity of the instrument. Those old instruments are not merely show pieces. They are not like the ancient museum parchments kept sealed in light-protected cases, and exhibited on occasions only for a moment. They are live things, working hard every day in the hands of the great violinists and 'cellists of our time. They stand as the product of a skill in craftsmanship which grew in an atmosphere sympathetic to it. There was in the air of sixteenth and seventeenth century Italy the spirit of the making of these instruments so that despite the meager knowledge of the principles of acoustics, despite the primitiveness of the tools and despite the ignorance of the chemistry of the varnishes, a result was achieved which, even to-day, transcends the efforts of modern skill. Machines can make many things better than the hand of man; but there are some things born of the hand of man and of the heart which no lifeless thing can duplicate. The spirit which guided the master violin-makers of old could hardly thrive in the civilization which has seen the rapid growth of the machine age. The painters could not live, and indeed would not be content to live in this age with the return with what they wish to paint might bring them. They would have to paint advertisements, and portraits of uninteresting people who paid them well for it.

If and when the day comes in which, through a greater leisure, these great arts and other non-utilitarian activities can claim once more an adequate proportion of the time and sympathy of mankind, then perhaps we may regain some of the things which mankind seems to have lost. It is for a new generation such as you represent that this millennium awaits. When it comes, see that you use it well.

NOTE: Acknowledgment is here made of the courtesy of the Macmillan Company in permitting the inclusion on pages 433, 437, 438 and 441 of certain quotations from the speaker's book, "The Architecture of the Universe," Macmillan, 1934.

THE ORIGIN OF CONTINENTS AND OCEANS

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AMONG the very interesting and puzzling problems in the field of geology and geophysics is that of the origin of continents and oceans. If we could solve this one, it is probable that much light would be thrown on many other geological problems.

There have been many hypotheses regarding the origin of oceans and continents, but most of them seem to conflict with the laws of physics and mechanics and therefore seem to be untenable. The only hypothesis that seems to be a reasonable one, and this has some difficulties, was advanced many years ago by Sir George Howard Darwin, son of the naturalist, Charles Darwin. He advanced the idea, and seems to have demonstrated it to the satisfaction of astronomers who have succeeded him, that the moon is gradually increasing its distance from the earth because of tidal friction. He worked backwards and found that at some time in the past, not so very long ago, astronomically speaking, the moon was exceedingly close to the earth. This led him to the opinion that the moon probably was formed of material that had been thrown off from the earth as a result of tidal forces. It would naturally be the surface material that would be thrown off. It is interesting to note that the mean density of the moon is about that of the denser terrestrial rocks, allowance being made for increase in density with depth under the pressure of lunar gravity.

The moon seems to be somewhat different from the other satellites of our solar system. Generally these satellites are small in comparison with their primary planets, sometimes very small, but the moon is fairly comparable in size to the earth, its radius being about one quarter of the earth's radius. Conceivably, the moon might have been formed as an independent planet and later have been captured by the earth's gravitational attraction, but the idea that the earth and moon were once parts of a single mass is an attractive speculation.

In any body like the earth there is bound to be a tidal rise and fall of its surface as it rotates relatively to another body that lies within a reasonable distance of it. This is true, even though the material composing the rotating body is solid and should have the rigidity of steel. For the earth there would be tides of its solid matter as well as tides in its oceans.

All tides on the earth are caused by the differential attraction of the sun and moon on different portions of the earth. When the sun and moon are in conjunction or in opposition the tide-producing forces are at a maximum. Halfway between these tides we have the minimum tide-producing forces, which give us the low or neap tides.

Since the earth was first formed, no matter how, tides must have been produced by the sun as the earth rotated on its axis. The high tides would occur at intervals equal to half the time required for the rotation of the earth relatively to the sun.

Each body, such as the earth, has what might be called a natural period of oscillation or vibration. If the earth were acted on by suddenly applied forces and a vibration resulted, the period of vibration would be that which is normal to this great mass. Darwin postulated that the period of the rotation was at first very rapid and finally decreased as the

result of tidal friction till the tidal interval approximated very closely to the period of the free vibration of the earth. As the two approached complete accord the tides must have become greater and greater. As the bulge on the earth caused by the tide-producing forces of the sun increased, the earth became unstable and, according to Darwin, a disruption occurred. If this actually happened, probably the tidal bulge on the side of the earth towards the sun was more attenuated than the opposite bulge, so that at the time of greatest instability only one mass would have been detached from the earth. After this disruption had occurred the period of the tides and the period of the free oscillation of the earth differed by such an amount that the tides again became normal.

One frequently notes the effect of a repeated and periodic application of a force to a body which can oscillate, and how a slight force often repeated increases the vibrations or oscillations of the mass. If one takes a tub of water and lifts one edge a small fraction of an inch and repeats the lifting at such intervals as to synchronize with the oscillation of the water in the tub, these oscillations are made very large. In fact, they become large enough to cause the water to spill over the edge of the tub, unless the water is very shallow in comparison with the depth of the tub. Again one frequently notes the vibrations of a suspension foot-bridge when a number of people walk in step across the structure. In fact, a body of troops marching across a suspension bridge is ordered to break step in order to prevent violent vibrations.

Darwin did not cover the question of oceans and continents in his discussion of the possible formation of the moon by tidal effects, but, shortly after he proposed his theory, the Reverend Osmund Fisher, a British geophysicist, advanced the theory that the moon could have been formed from the earth in the manner postulated by Darwin, even though a solid shell or crust had been formed. He reached the conclusion that if the moon had been formed by a disruption of the earth after the crust had appeared, the disruption would have left blocks of the crust to form continents and islands, and that the area from which the material was detached to form the moon would be depressed because of the absence of the light crustal material.

This idea of Fisher's has been discussed by subsequent writers. Some have raised objections to the hypothesis, while others have strongly supported it. It seems to me that what we should do in attempting to explain any natural phenomena is to analyze each hypothesis that has been advanced and to hold to the one that apparently has the greatest strength. In my judgment this hypothesis of Fisher's, based upon the ideas of Darwin, meets this criterion.

We know from gravity data that the earth's crust is at least in an approximate state of equilibrium. It has been found that the probable depth to which the crustal material extends below sea level is sixty miles. This depth may be anywhere between forty and eighty miles, but in any event the earth's crust is like a huge blanket wrapped around the central part of the earth. This blanket is composed of material having residual rigidity. It will break if forces acting upon it exceed the limiting strength of the material. On the other hand, the material that lies below the crust has no residual rigidity to even comparatively small forces acting through geological times measured in hundreds, thousands or some greater number of years. This crustal blanket exerts approximately the same pressure on equal areas of the surface of the nucleus of the earth. It is similar to a great ice sheet on a lake or on the Arctic Ocean. The blanket stands high in some places, as continents and islands, because the material forming the crust below those elevated areas is less

dense than the average. The oceans are depressed because the material composing the crust beneath them is denser than normal.

This condition of equilibrium of the earth's crust is called isostasy. Isostasy is not a force; it is merely a condition that is approached by the crustal matter acting under the force of gravity.

The mineralogists have contributed to our knowledge of the densities of crustal material. They find that the igneous rocks of islands in the oceans have the heavier elements present in larger percentages than are found in the igneous rocks of the continents and of the large islands such as New Zealand and Australia. Then, again, the seismologists have furnished data regarding the densities of crustal material. They do not measure the differences in density of crustal matter, but they do find that the rate of transmission of the earthquake waves is faster under the oceans than under the continents. Presumably the crustal material under the oceans, being the more elastic, is denser.

Geologists have speculated for many years as to why the continents and oceans should continue to exist. Now that the geodesists, mineralogists and seismologists have learned that the material under the continents is lighter than that under the oceans the problem is solved. But there remains the problem of discovering how these differences could have occurred.

We have several theories regarding the origin of the earth. It is not possible to discuss those theories in this short paper. We may mention, however, that there are two that have many adherents: One, that the earth was pulled away from the sun by the attractive forces of a star passing close to the sun, or perhaps knocked off by an actual collision; and the other, the so-called planetesimal hypothesis. According to the first, the earth was a molten mass that gradually cooled and solidified. According to the planetesimal hypothesis the earth never was molten. It was formed by small masses collected together by their mutual attraction. We do know that the earth's interior must be hotter than at the surface. This is indicated by volcanoes, hot springs, outpourings of lava sheets and by the temperatures of wells and mines. The increase of temperature with depth varies for different places on the earth's surface, but a fair average is an increase of fifty degrees centigrade for the first mile. If that change per mile should remain constant with depth, the temperature twenty-five miles below the surface would be 1250° C, which is great enough to fuse rocks at the earth's surface.

No one can tell what the temperature of the interior of the earth was before the disruption of crustal material took place, but it seems to me to be reasonably certain that the temperature must have been very high and that the subcrustal material was more plastic than it now is. Observations for earth tides made by Michelsen and Gale showed that the earth as a whole is as rigid as steel. Is it not possible, if the rigidity of the earth were as great as that some billions of years ago, that the tide-producing forces of the sun would have been insufficient to distort the earth's form to the extent of making it unstable? Even if the disruption had occurred with a very rigid earth, however, there would be no difficulty in having the scars left by the removal of the crust healed by the upward movement of subcrustal material. The gravitational forces would have been so great that upon the removal of portions of the crust the subcrustal matter would be forced upward to fill the spaces. Since the subcrustal matter would be denser than the crustal mass removed, the new surface of the earth would be lowered over those areas where the crust had been torn away. If the subcrustal material had been very plastic or almost fluid, then the tide-producing forces

would have been more effective in distorting the former shape of the earth. Even though the earth may have been solid there would undoubtedly have been a breaking up of crustal matter, just as would no doubt occur to-day, because the surface of the ovoidal earth just before disruption would have been many million square miles greater than for the spheroid. We really have no definite evidence in favor of either a very solid earth or a very plastic or liquid one.

In any event, there is no explanation that has ever been advanced regarding the distribution of crustal material as we have it that is not subject to adverse criticism except this hypothesis of Fisher. No one can say that Fisher's hypothesis is true, but it is logical and in any event it does no violence to isostasy, or the equilibrium of the earth's crust. It is impossible on a molten earth gradually cooling to have the light material, which must have been present around the whole earth, pushed together into great masses to form continents. There is no force available inside or outside the earth which could have caused such a segregation of surface matter; nor on the planetesimal hypothesis can we imagine the granites, composing at least the outer portion of the crustal matter beneath continents, collecting in isolated masses. There apparently is a complete absence of granitic material under the oceans, and therefore it would seem to be logical to conclude that when the earth's crust was formed, a layer of granite covered the whole earth and that by some process it was disrupted, and parts of it went off into space. Whether the moon was formed this way or not makes no difference, but apparently there must have been a disruption or we could not have the present distribution of crustal material.

It has been estimated that if the hypothesis of Darwin is true, the earth would have to be distorted into the form of an ovoid with its major axis approximately twice as long as its minor axis before the disruption of a portion of the mass could occur. If the earth were to assume the ovoidal shape, with its major axis twice the length of the minor one, the surface of the ovoid would be approximately fifteen million square miles greater than the surface of the spheroidal earth. This would mean that there were many spaces on the earth's surface before the disruption from which the granite blanket was absent. Those spaces would be filled almost as soon as formed by the upward movement of the subcrustal material under gravitational forces. Those spaces would not be closed again as the major axis changed its position in the earth's mass, but there would be a movement up and down of portions of the earth as the tidal bulge moved around its mass in response to the tidal forces. It is rather interesting to note that the two coasts of the Atlantic are so nearly alike that they have the appearance of the shores of a great river. Is it not possible that North and South America could have been torn away from the crustal material that forms Europe and Africa just before the disruption occurred?

I can imagine, if the oceans and continents were created in the way that we are discussing, that there would be many small fragments of the original crustal material left behind. We have islands in all the oceans and also ridges and plateaus that do not reach the surface of the water. It is possible that these elevated portions of the crust under the ocean represent the presence of some of the original crustal material.

Some other hypothesis may be advanced to account for oceans and continents, but the one which we may label the Darwin-Fisher hypothesis certainly is the most probable one that has been advanced up to the present time. The question may be asked, "When did all this occur?" The answer must be, "A long time ago." According to the best

geological evidence the present sedimentary age of the earth began about one billion six hundred million years ago. It is reasonably certain that the continents and ocean basins were formed prior to that time, for without erosion there could be no sediments. In order to have sediments we must have running water. Running water carries material from high areas to low ones. If the original crust of the earth had been uniform in elevation with only local humps and hollows, the waters that were on the earth would have stood at about the same depth over the whole surface. Then, no matter how much rain there might have been, in the absence of exposed land there could not have been any erosion. It would seem from this that there must have been an irregular surface of the earth at the beginning of sedimentation.

Erosion and sedimentation are really very important factors in the changes that occur on the earth's surface. We have a number of facts that are quite valuable as the basis for geological and geophysical investigations and speculations. We know the shape and size of the earth with a very close approach to accuracy. We know the mass of the earth, the densities of its surface rocks and the approximate age at which sedimentation began. We know that we now have rainfall at the rate of approximately thirty inches per year over the land surface of the earth. It is many times that in some areas and in others there is scarcely any rain at all. By using an average of thirty inches we would have at that rate approximately one mile of rain in two thousand years. But since the sedimentary age is eight hundred thousand times that much, we can see that if the rate of rainfall has been uniform there could have been eight hundred thousand miles of rain.

The rain falling to the earth carries to the ocean waters vast quantities of material in suspension and solution. According to the results of the analyses of river waters by scientists of the U. S. Geological Survey, the mass of material that goes to tide water in nine thousand years from the United States alone is equivalent to a blanket one foot in thickness over this country. This rate of erosion is small in terms of the length of human life, but in geological times the amount of erosion that could have occurred is enormous. One mile of erosion would have occurred in forty-five millions of years, if the configuration of the surface of the United States could have been maintained as it now is. But this is only about one thirty-fifth of the total time during which there has been rainfall, erosion and sedimentation. Great piles of sediments are accumulated at the mouths of rivers, in inland seas and lakes and along our shores. These accumulations certainly affect the isostatic equilibrium of the earth's crust. The crustal material will sag under the added load. Then again the areas from which the sediments are derived become lighter and, therefore, there is a tendency for them to rise by the intrusion into crustal space of subcrustal material. The balance is maintained to a rather high degree of perfection. This is indicated by gravity and other geodetic data that have been accumulated over many parts of the earth's surface.

Geologists tell us, and I believe there is no opposition to this idea, that all mountains and plateaus occupy areas that were once below sea level and were receiving large quantities of sedimentary matter. There must, therefore, be a relation between sediments and the formation of mountains and plateaus. Is it not possible that erosion and sedimentation are the principal factors in the changing elevations of the earth's surface?

If the temperature increases with depth, then, as the crustal material is

pushed down by the weight of the sediments, the matter would occupy spaces that are hotter than those previously occupied. Perhaps the eventual rising of the isogeotherms would cause an expansion of the crustal matter and perhaps a change of physical state, thus creating a plateau or mountain range.

Areas that were once occupied by mountains and plateaus are now below sea level. Here we have the opposite process. As the crustal material rises, as erosion lightens the crust, matter is brought into higher and colder regions and eventually as it cools to the normal temperature of its new position, the matter then contracts and forms a depression or trough into which new sediments will be deposited. There is evidence that mountain areas have gone up and down more than once, and it is possible that the explanation may be found in the effect on the equilibrium of the crust of the unloading and loading resulting from erosion and sedimentation.

We must acknowledge that we are still in the speculative stage regarding the cause of the existence of ocean basins and continental masses. Yet speculation is very fruitful in scientific research. Without speculation we become merely observers of phenomena or collectors of data. The hypotheses enable us to make tests and to observe and collect with a greater degree of effectiveness. It is possible that in the future more light may be thrown on this very interesting and important geological phenomenon of oceans and continents. The Darwin-Fisher hypothesis may be substantiated or the evidence may be so strong against it that it will have to be abandoned.

ON THE EXISTENCE OF FERROMAGNETISM

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I WISH to revive a question, not to answer one. Why does ferromagnetism exist? The question was probably first asked by that early shepherd who, as we are told, discovered the phenomenon for the Greek philosophers, and I want to suggest that it is still, in a certain sense, an unanswered question.

It has been answered at various times in languages that would not satisfy the modern demand of an explanation—that it correlate phenomena. And in the times of the recent classical physics, probably the nearest thing to an answer was proposed by Weiss, who, as you know, assumed that the elementary magnets, whatever they be, have their rotations dictated not only by the usual statistical forces of temperature perturbation and the comparatively weak influence of a magnetic field (these effects alone constitute a theory of paramagnetism) but also by a strong orienting force of unknown nature but in strength proportional to the magnetization and tending to align the elementary magnets along the direction of magnetization. In other words, he simply assumed that the elementary magnets are coupled together in such a way that, if several of them point in the same direction, they conspire to make many others point with them. It is apparent that such a mutual orienting force, if strong, could amplify the feeble efforts of an external magnetic field in turning the elementary magnets parallel to one another, and thus give rise to the existence of ferromagnetism. It is equally apparent that such a mutual orienting force does not have as a consequence either hysteresis or ordinary remanence, for it only tends to hold the elementary magnets parallel to one another, not parallel to any particular

direction in the metal. These technically vital phenomena, dependent upon preferred directions of magnetization, we shall lay aside as not essential to the theory of the existence of ferromagnetism.

This ad hoc assumption of Weiss is so successful in correlating the maximum intensities of magnetization at various temperatures, for example, that we might accept it as an answer to our question. But to the curious mind the assumption merely challenges with the question anew: Why do the elementary magnets have a strong tendency to point parallel to one another (and, incidentally, what are the elementary magnets)?

Because of the crystalline nature of metals, we feel sure that no bit of matter larger than an atom is free to rotate within a metal. So we conclude that the elementary magnet is an atom or a part thereof. This being the case, it can easily be estimated, by using the measured magnetic properties of the individual atoms and the known density of atoms in the metal, that the *magnetic* force between the neighboring atoms (or any parts of atoms) is about a thousand times too weak to explain why ferromagnetism should exist at ordinary temperatures.

The question, "What are the elementary magnets?" can be answered quite definitely by a nice combination of theory and experiment. The theory of atomic spectra, together with experimental information on that subject, tells us that there are two types of rotation in an atom—two types of angular momentum—one due to the to-and-fro motion of electrons in the atoms, and the other type due to the fact that each electron is spinning like a top. Spectra tell us, further, that a certain amount of the spinning momentum carries with it just twice as strong a little magnet as does the same amount of angular momentum due to to-and-fro motion. When we magnetize a bar to a certain strength, the amount of angular momentum that we must twist into the direction of the axis during the process depends on whether we are turning little magnets due to electron spin or due to to-and-fro motion or both. We know from experience with gyroscopes that, when we try to twist an angular momentum in one direction, it produces a twist in quite another direction. So it is that, when we apply a magnetic field to twist the elementary magnets in a bar, the little magnets are first rotated sideways, but some other forces within the crystal act like friction in the bearings of a gyroscope, and the whole bar receives the twist, while the elementary magnets rotate into the direction of the field. By measuring very delicately how much the bar is twisted, it is possible to determine whether the amount of angular momentum is that of the spin or that of the to-and-fro motion, and experiments of Barnett show that it is the spin. So the electron spin is the elementary magnet.

The theory of atoms and the principles of gyroscopes have helped, and the theory of molecules also helps our query. We think of bringing two atoms slowly together. Each consists of a single electron gyrating to and fro about a nucleus. Each atom has as much positive as negative electricity, so they don't attract each other when apart. When they get near enough to one another that the two regions through which the electrons gyrate begin to overlap, then the electrons affect one another's motions according to the strange rules of a very important game (Pauli wrote the rule-book of this game, which is one of the laws of nature—it explains many things). When the electrons are spinning in the same direction, they try to stay apart and shun the space in which the two regions overlap! (When, contrariwise, they spin in the opposite directions, they tend to congregate!) If that

space in which the regions overlap is far away from the two positive nuclei, then the most important effect of the aloofness of the two electrons (spinning alike) is that they tend to inhabit regions into which they would have tried to push each other (because of their like charges) anyway, so their average energy is reduced because of their aloofness. The two electrons will then spin in the same direction in order to attain low average energy. (There is an opposite tendency when the nuclei are so close together and so close to the space in which the regions overlap that they make it a place of very low energy for the electrons.) This tendency of the electrons to spin in the same direction (and point their magnets in the same direction) is caused, we see, by electric forces, not by magnetic forces, and the electric forces are much the stronger. In fact, it can be calculated that, in a simple molecule like this, the tendency of the two electrons' spins to point the same way is strong enough that, *if* it should also exist between many electrons inside of a metal bar, it could be the cause of ferromagnetism, and the answer to our query. This important suggestion is due to Heisenberg. That "*if*" is the unanswered part of the problem. It seems quite possible that the tendency might not exist when an electron has neighbors on all sides, because if an electron in a metal tries to avoid one neighbor, it might merely back up into another, a thing that would not happen in the simple molecule. There are other reasons why the tendency toward similar spins might not exist in a metal. One of them involves the wave mechanics of the molecular problem a little more explicitly, so we shall here make a short wave-mechanical digression, repeating in another language some of the things we have just discussed.

When the two atoms of a molecule are separated, each has energy E_0 and its electronic behavior (and spin orientation) is dictated by the function ψ^a_α which satisfies the simple wave equation

$$(\Delta^a + V^a_\alpha - E_0)\psi^a_\alpha = 0.$$

Here α denotes which nucleus, and a, which electron, we are describing. The wave equation of the two atoms as they begin to approach one another contains an energy E which we suppose to differ by only a small amount (ϵ) from the total energy $2E_0$ of the two atoms far apart, $E = 2E_0 + \epsilon$. There also appear potential energy terms $V_{\alpha\beta}$, V^b_α, and V^{ab} representing interactions between nuclei, between nuclei and electrons, and between electrons, respectively:

$$(\Delta^a + \Delta^b + V_{\alpha\beta} + V^a_\alpha + V^b_\beta + V^b_\alpha + V_\beta + V^{ab} - 2E_0 - \epsilon)(\psi^a_\alpha\psi^b_\beta - \psi^a_\beta\psi^b_\alpha) = 0.$$

The last factor, an anti-symmetric combination of products of the single-electron functions ψ^a_α, is in that simple form an approximate solution of the equation for the case in which we are most interested, with the two electrons spinning in the same way. If, in this case, we multiply the equation by the simple product $\Psi^a_\alpha\,\Psi_\beta$ and integrate over the coordinates v, using the simple single-atom wave equation which states that some of the terms add to zero, we obtain directly the expression:

$$\int \Psi^a_\alpha\,\psi^b_\beta\,(V_{\alpha\beta} + V^{ab} + V^b_\alpha + V^\alpha_\beta)\;\psi^a_\alpha\psi^b_\beta\,dv$$
$$-\int \Psi^a_\alpha\,\Psi^b_\beta\,(V_{\alpha\beta} + V^{ab} + V^a_\alpha + V^b_\beta)\;\psi^a_\beta\psi^b_\alpha\,dv$$
$$= \epsilon\int \Psi^a_\alpha\,\Psi^b_\beta\,(\psi^a_\alpha\psi^b_\beta - \psi^a_\beta\psi^b_\alpha)\,dv$$
$$= \epsilon\,(1 - S^2)$$

where $S = \int \psi^a_\alpha\psi^a_\beta\,dv^a$. In the last step we have used the "normalization" of the wave functions, and the term S enters because of the fact that the wave functions of the two atoms overlap in a simple way. The interpretation of this equation is important. The first integral is the ordinary average of the ordinary potential which is introduced into the problem when the atoms approach one another.

The second integral, starting with the negative sign, is known as the "exchange integral," and comes into the problem just because the Pauli rule states, in this kind of calculation, that we must use anti-symmetric solutions of the wave equation, made by interchanging the coordinates of the electrons. If it is positive, it helps to lower the energy of this state of two like spins. It is a quantitative measure of the effect that we ascribed above to the aloofness of similarly-spinning electrons. But, in order that the left member may be interpreted simply as an energy ϵ, the term S^2 on the right must be zero, which is not the case. We see that this term S^2 likewise entered the problem because of the possibility of interchanging the coordinates of the two electrons. In this simple atomic type of problem it usually leads to only a small correction.

But, in the similar but more complicated problem of the behavior of electrons in atoms in a metallic crystal, very many such terms S^2 enter the problem, in fact, as many as there are pairs of neighboring electrons to be interchanged! This is, for even a small crystal, a tremendous number of terms—about N, the number of atoms in the crystal. But worse than this, there are about N^2 terms S^4, and so on. Even if S were only a hundredth or so, such a great number of terms, in place of the single term S^2 above, would be expected to make a great difference in the result of our calculation. Yet this tremendous number of terms have been simply neglected in the best calculations which have yet been made to explain theoretically the strong coupling between the electrons in a ferromagnetic metal.

The accuracy of the calculation thus seems to depend in an ugly manner on the size of the crystal. Physically, the region in which spontaneous magnetization exists is probably rather small, due either to "mosaic" structure or to demagnetizing fields, so the number of atoms in our problem need be only a million or so. But even so, the amount of overlapping, which determines S, would have to be extremely small if the calculation for the crystal is to mean anything, and this would make the exchange integral and the coupling between the spins very small indeed. In this negligent approximation of Heisenberg, the theory could only be applied to very distended crystals, and would predict ferromagnetism for them only for temperatures within a few degrees of the absolute zero (which is hardly what we mean by ferromagnetism!).

Still we might use the theory to placate our curiosity, being content with a weak ferromagnetism of a distended crystal, if it were not for the fact that, as the crystal contracts, another strong tendency comes into play to oppose ferromagnetism. It is the rule forcing electrons of overlapping atoms not to move with the least possible momentum, but to acquire a considerable amount of kinetic energy, and more if their spins are similar than otherwise. (When the electrons wander through the same region, the Pauli rule states that the electrons with like spins must stay apart on a momentum scale, so to speak, rather than apart in distance.)

Because of the difficulty of making an adequate theory of ferromagnetism, perhaps it is worth while to examine some of the consequences of this very deficient type of calculation. We have already seen that there is a tendency toward like spins for the two electrons of a simple molecule only when their regions overlap in a space midway between the two nuclei and not near either nucleus. For this to be so, it is necessary that the region of an electron of one atom does not extend far beyond the midway point. The region of an electron must, then, be comparatively small, and, for ordinary crystal dimensions, it must be smaller than

the region of an outside electron of any atom. So it would seem that we should blame ferromagnetism on some of the inner electrons of the atoms, the regions of which are smaller. But the inner electrons of atoms are ordinarily so arranged, because of the Pauli rule again, that their spins stay opposite in pairs and just cancel out the magnetic effects of one another. From spectra it is well known that this is not always true, exceptions being found in that part of the periodic table around vanadium, iron, and nickel. Here we seem to have a rough indication of why ferromagnetism does not appear in all metals. It is also noteworthy that the regions of these "exposed" inner electrons are more compact for iron, nickel, and cobalt than for other elements (an idea due to Slater).

Finally, let us consider the possibilities of calculating this effect from a new and less erroneous point of view. Considerable advance has recently been made in the theory of cohesion of metals (by Wigner and Seitz and by Slater) by finding with rather tedious numerical methods a set of approximate functions to describe the motions of an electron through a crystal, with various possible momenta, and allowing for the fact that the peripatetic electrons still have some connection with the atoms. These functions are reckoned by considering only one sample region of the crystal, approximately spherical, belonging to one atom, since the function practically repeats itself in other regions. Each of these functions describing a possible motion tells a possible energy of an electron, and the possible energies come in clusters. The cluster or band of energies arising from the outside electrons of the atoms is quite broad, and there are, in simple metals, half as many electrons as possible kinds of motion, so each electron has (for the lowest total energy compatible with the Pauli rule) one of the kinds of motion and one of the energies in the lower half of the band. Besides reckoning these functions and energies, we must find out how much difference in the energy the "aloofness" of the electrons makes. This is not so very difficult for the outside electrons of sodium atoms in a crystal, because outside electrons have not very much momentum and therefore have long "wave-length," which makes their density throughout most of the region fairly uniform. This effect has been included in calculating the cohesion of sodium, for example.

For the inside electrons, a similar but probably narrower band of translational energies exists, and the energies should be calculable in just the same way. However, these inner electrons, being nearer the nucleus, have more momentum and shorter wave-length and considerably less uniform density, which makes the calculation of the "exchange" or "aloofness" effect more difficult than in the cases for which it has been carried out. The method is particularly well adapted to calculate only the increase of translational energy accompanying similarity of spins, which would have to be exceeded by the decrease of energy due to the greater average distance between the aloof electrons, a quantity more difficult to reckon. But we may hope that this new method will lead to a much more satisfactory answer than we yet have to our query, "Why is ferromagnetism?"

SCIENCE SERVICE RADIO TALKS

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THE SCIENCE OF STUDYING HUMAN BEINGS

By Dr. HARVEY N. DAVIS
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SOME years ago an engineer of my acquaintance dined one night with the head of a considerable industrial establishment. In the course of the conversation the manager happened to mention with some pride an improvement he had recently made in the specifications on which they were buying one of the raw materials needed in their manufacturing operation. Instead of registering the polite appreciation that the occasion demanded, my friend blurted out: "Why do you waste your time over that sort of thing? For years you have been fussing over your raw material specifications that were already good enough. At the same time, you've been spending more each year on labor than on all your raw materials put together and spending it as blindly as if human beings were neat little packages of some thoroughly standardized product that needed no investigation beyond looking at the label. Why don't you put just a little of the same sort of engineering brains into buying your labor that you have put for years into buying your iron and copper and rubber and silk?" The industrialist looked at the engineer awhile, and then said, "All right, I'll call your bluff; you're hired; report at the plant next Monday, and we'll see what you can do." Out of that conversation grew the work that I am going to talk about this afternoon; out of it also grew a set of work samples and an employment office technique that a few years later attained and maintained for three years in that plant a labor turnover record of only 6 per cent. per annum under conditions where from 30 to 60 per cent. would have been not unexpected. And this is but one example of many that could be drawn from modern industrial psychology to show that there is beginning to arise in the world a real science of studying human beings.

One difficulty is basic in this field. It is that no two human beings are alike. Any laboratory can procure for study a sample of practically chemically pure copper, and this sample will be almost exactly like those that other laboratories have studied previously; this is what has made it possible to determine what we call "the properties of copper." But no laboratory can find a human being exactly like the one that another laboratory studied last week; this is what makes it impossible to talk about "the properties of human beings" or "the laws of human nature" in any but the vaguest of senses. Nevertheless, a scientific approach to the problem does seem to be possible, and the basis of it is twofold.

In the first place, the use of the statistical method makes measurement in the scientific sense possible to a surprising extent. If we try to compare one individual with another we get nowhere, because of unpredictable individual differences. But if we compare one considerable group of individuals with another and talk averages or medians or mid-means, we get measurements that are definitely reproducible from one group to another, and from one laboratory to another. And it is only when measure-

ments become reproducible that we have anything that can properly be called science.

The second basis for a scientific approach to the problem is the fact that we seem to be able to separate out of the infinitely complex mental make-up of individuals a number of independent powers or abilities or aptitudes that can be measured and studied each by itself. This greatly simplifies the problem, but it forces us to be constantly on our guard against unconsciously assuming that the relatively few aptitudes that can as yet be measured are the whole story, or even that we can ever hope to get the whole story by laboratory methods of this kind.

As an example of what we mean by independent abilities or aptitudes, let me describe two very simple tests that were worked out by my friend the engineer as an aid in selecting girls for factory work. The first is what is called a finger dexterity test. It uses an aluminum slab in one end of which are a hundred holes arranged neatly in ten columns and ten rows. In the other end is a shallow tray containing something over three hundred pins, that is little pieces of aluminum wire about an inch long and a sixteenth of an inch thick. The job is to pick up three pins at a time and put them in the first hole, then three more in the second hole, and so on until the hundred holes are filled. With a stop-watch the observer measures how long the subject takes for the job. This simple test has proved very useful in selecting nimble-fingered girls for electric-meter assembly and other hand work on small objects.

There were, however, other sorts of work in the factory, for example, jewel inspection for pivot bearings, that had to be done not with the unaided fingers, but with a pair of tweezers or with some other small tool interposed between the hand and the work. So a slight variation of the test was devised, in which the subject used tweezers to pick up one pin at a time for each of the hundred holes.

The two tests are so nearly identical, involving as they do the same fingers of the same hand, the same pins, practically the same holes, and practically the same job, that it seems almost foolish to use both tests, except perhaps as corroboration each of the other. One would suppose that nearly every one who did one test well would do the other well also, and conversely. Indeed the company had unconsciously assumed this for years, for they had made it a practice to put all newly hired girls on finger work for a year, and then to transfer the best of them to tweezer work as occasion required. But when the thing was tried out in the laboratory, the two aptitudes, finger and tweezer dexterity, were found to be almost wholly independent of each other. Both the best and the worst quarters of a large group of girls tested for finger dexterity would scatter all over the scale on tweezer dexterity; one would be exactly as likely to find a good tweezer operative among the worst finger operatives as among the best. Indeed one stood precisely the same chance of getting one by picking a girl at random from the applicants in the employment office. Possessing or lacking finger dexterity gives practically no indication whatever as to whether a given individual also possesses or lacks tweezer dexterity. Each of the two abilities must be measured separately, and it is pure chance whether any given individual will be better than average at both, or worse than average at both, or good at one and poor at the other. This is what I mean by calling these two abilities independent aptitudes.

Indeed these two aptitudes are so independent as to present one of the somewhat uncommon cases in which striking sex differences emerge under laboratory conditions. Women seem to have distinctly more finger dexterity than men, only about 10 per cent. of a large group of men being, in general, as good as the top quarter of an equally large group of

women. On the other hand, men have more tweezer dexterity than women, only about 15 per cent. of any large group of women being as good as the top quarter of an equally large group of men. That is, women excel whenever the hand does the work; men excel whenever the hand uses a tool to do the work.

Why this should be, what racial inheritance or universal environmental or educational difference is here in evidence, my hearers can guess as well as I can. The facts have, however, an interesting industrial significance. There are in factories many departments where the work is distinctly of the finger dexterity type. In such cases one almost always finds that the management has learned by experience to use women operatives. Similarly, in departments where the use of small tools is characteristic of the job, men operatives are almost invariably used. But occasionally one comes across a department where the work requires a mixture of finger and tool dexterity, where operatives should rank high in both aptitudes. In such cases it will usually be found that the management has been uncertain which type of operative to use, that they have tried at times men, at times women, at times both working side by side. Furthermore, in such cases, one usually finds a higher labor turnover, a higher percentage of rejections by the inspection corps, and a higher record of customer complaints than in other departments of the same plant. All these lessons, learned by experience, find explanation in the facts about finger and tweezer dexterity that have emerged from the laboratory. And all these difficulties can now be minimized by any employer who is ready to make intelligent use of laboratory technique in his employment office.

I have given you a striking example of two abilities that seem closely related and yet prove to be almost wholly independent. Let me now give an example of an opposite sort. Bookkeepers and accountants deal with figures, usually tabulated in columns. A number-checking test has therefore been devised in which two columns of figures are compared, item for item, and checked as the same or different. The job is timed with a stopwatch, and an experimentally determined time penalty is added for each error. This test has been found to work well, both in characterizing people known to be good bookkeepers, who do the test much better on the average than unselected subjects, and in selecting good bookkeeper material for training.

Stenographers and secretaries, on the other hand, deal not with *numbers* that have to be read digit by digit, but with *words* that are read as a whole, a single glance associating a meaning with a group of letters not perceived separately. This ability can be measured by a word-checking test in which the words in two columns are identified as the same or different. One would be inclined to guess that checking figures and reading words are mental processes more different from each other than picking up pins with one's fingers or with tweezers. Nevertheless, exactly the opposite proves to be the case. Both bookkeepers and stenographers do both tests well, and a high or a low score on either test is a strong basis for predicting that the subject will perform correspondingly well or poorly on the other test. One single clerical aptitude enables a person to deal effectively with either number or letter symbols, whereas neither of the dexterities spills over into the other dexterity field.

Perhaps these examples have sufficed to show you what we mean by independent aptitudes, how important they may be in industry, and how useless it is to attempt to guess without careful experimentation what the cross relationships are between various abilities and powers.

But there are also educational advantages that may be expected to flow from studying individuals in the impersonal fashion, and with the constant effort to measure things quantitatively, that are characteristic of science.

For example, one of the chief problems of an educational administrator is the wise selection of his freshman class. American colleges have elaborate admission systems, including lists of subjects that are supposed to constitute adequate preparation, a highly organized system of giving and grading entrance examinations, carefully guarded procedures of certification and jealously maintained standards of admission, and yet our survival rates are often shockingly low. Indeed, it has been said that scarcely a third of those who hopefully enter American engineering schools each fall manage to graduate in due course four years later. At least half of them probably never graduate at all, and in many cases this means not only a waste of time and money but also thwarted ambitions and bitter disillusionment that leave lasting marks on a student's personality and character.

Fortunately, criteria that will help us to recognize impending scholastic disaster when students apply for admission to college are beginning to emerge from the intensive scientific study of human beings that is going on all over the country, so that we can warn and watch and help, even if we can not always dissuade or exclude our weaker students. All these criteria must, of course, be used with great caution; they indicate rather than prove that failure will ensue; in fact, by suggesting the possibility of failure, they sometimes help us and our students to avoid it altogether by special instruction on our side and by enlightened self-discipline on theirs, and so frequently do much good.

Now it happens that the clerical aptitude tests mentioned a moment ago are useful predicters, not only for commercial and business schools, but for all sorts of academic work. There is so much paper and pencil work in any modern educational process that a student blessed with high clerical aptitude has a distinct advantage over one not so endowed.

A still more significant predicter is a vocabulary test that was developed at Harvard some ten or fifteen years ago, and improved and developed at Stevens during the last five or six years. What it apparently measures is the ability to get things out of books, which is, of course, fundamental in any sort of schooling.

And for engineering schools there is another wholly independent aptitude of great importance, namely, the ability to visualize things in three dimensions, to see vividly in one's mind the reality of which a blue print is, to many people, an utterly meaningless portrayal. For this aptitude also several valid tests are now available.

As these and other tests, present and future, enable us to analyze and, in a measure, understand the mental powers of our students, both we and they will do better work, and enjoy it far more abundantly. Perhaps the happiest time in my year is the two summer weeks that we at Stevens devote to our Junior Camp, where, by such means as I have described, we try to help forty or fifty eager young preparatory school boys to study themselves and to decide intelligently whether they should choose an engineering school or an arts college. There we seem somehow to be anticipating the future, and realizing here and now a little of what the science of studying human beings is going to accomplish for mankind.

OUR HIGHWAYS, ARTERIES OF THE NATION

By Professor S. S. STEINBERG

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Of the many developments of the twentieth century, that of highway transportation has been the most profound and far-reaching in its contributions to our national life. Our highway transportation system has not only added immeasurably to the national wealth, but it has enriched the lives of our people socially and culturally. It has provided the foundation upon which has been erected a vast and diversified industrial structure that provides employment for both labor and capital in the manufacture, distribution and servicing of motor vehicles, in road-building and maintenance equipment, in the production and distribution of gasoline, oil and accessories, and in a variety of auxiliary services, including insurance, garages, parking facilities, roadside stands, hotels and many others.

With more than 25 million motor vehicles on our highways, sufficient in number to transport our entire population at one time, the business of highway transportation becomes one of the largest in the country. This is well borne out by some recent statistics. During 1934 the expenditure for new cars and trucks, for gasoline, oil and repair service and for highway taxes totalled eight billion dollars. Of this amount, collections of motor vehicle fees and gasoline taxes alone amounted to one and one quarter billion dollars. This means that motorists paid one out of every eight tax dollars collected. It is estimated that automobile tourists on vacation last year spent almost three billion dollars.

Considering total passenger miles of transportation last year, and excluding waterways, we find that highways carried more than 87 per cent., steam and electric railroads more than 12 per cent. and airplanes less than one per cent. of all passenger travel. There are more than 100,000 buses operating on our highways, and they carry annually two billion passengers, which is equal to one bus ride for every person in the world. The contribution of highways to the advancement of education is evidenced by the consolidation of rural schools, of which there are now more than 23,000 in the United States. These require the use of 70,000 buses which carry more than two and one half million school children each and every day in the school year. To provide this service, school authorities spent more than 48 million dollars last year.

Despite this evidence of the extensive use of our present highway facilities we find our highway system is far from complete. Of our total of more than three million miles of rural highways, only 5 per cent. is hard-surfaced and but 30 per cent. has received any kind of improvement. The remaining 70 per cent. represents more than two million miles of highways which are wholly unimproved. In addition we have about 260,000 miles of city streets much of which is urgently in need of improvement.

These statistics, as well as the personal observation of every motorist, make it evident that we are far from any saturation point so far as improved highways are concerned. There is great need for completing the trunk highway system of the states, for reconstructing and widening inferior roads to better standards, for improving city streets and for building a tremendous mileage of secondary light traffic roads. By-passes and alternate routes are urgently needed in cities

to avoid congestion and to promote convenience of motoring. Better roads and streets mean greater safety, better educational and social opportunities as well as greater economies for agriculture and industry. Improved highways are an investment, never an expense; they are self-liquidating and income-producing. They reduce automobile operating costs by savings in gasoline, tires, depreciation and repairs.

Our highway accident toll has so risen that in the United States alone last year almost 100 persons were killed, on the average, every 24 hours, while one person in every 100 of our population was injured in a highway accident. It is estimated that the burden of property loss and cost of accidents last year exceeded two and one half billion dollars. It is interesting to observe that our total expenditure for highway improvement during the same period was less than one half that amount. Widening, straightening and improving our roads will remove many of the causes of motor vehicle accidents and thereby protect life, limb and property.

One of the great hazards of highway travel, resulting from the fact that railroad building preceded our highway development, is that of railroad grade crossings. In addition to the constant danger they present to life and property, such crossings involve a great economic loss in traffic delays. About 1,500 persons are killed annually and three times as many injured in railroad grade crossing accidents. The new high-speed trains when considered in combination with high-speed vehicular traffic, focus attention on the great need for protecting motorists against the dangers involved, particularly at intersections of highways and main line railroads.

In all we have about 240,000 railroad grade crossings. The great number of these makes prohibitive the cost of completely eliminating them in the near future; for with an average cost of $50,000 for each grade crossing elimination, a project to abolish all crossings would cost twelve billion dollars. At least 30,000 of our crossings are extremely dangerous. At the present rate of progress it will take long after the year 2,000 before even the extremely dangerous crossings will be made safe.

Congress, recognizing the need for grade crossing elimination or for protection by the installation of safety devices, has provided 300 million dollars of emergency relief funds for this purpose to be expended by the state highway departments during the next two years.

While highway transportation has already greatly contributed to the advancement of agriculture, the lack of adequate farm-to-market roads is costing farmers considerable. These roads are generally located outside of the federal and state highway systems and have received scant attention in the past. More than two and one half million farms, or 42 per cent. of all farms, are located on unimproved dirt roads, roads that act as barriers between the farm and the market-place. Because his roads are impassable at certain seasons of the year, the farmer can not take advantage of the best price markets. We find that there are more than five million motor vehicles on farms and that farmers own 26 per cent. of all our trucks. The poor roads penalize the farmer by compelling him to assume the additional operating expense for his vehicle, thereby making the mud tax in wear and tear on farm transportation equipment enormous. Agriculture needs adequate year-around all-weather roads on which it can depend for the economical transportation of commodities.

The development of low cost farm-to-market roads will be of direct economic benefit to the farmer, will remove isolation in agricultural sections, will increase social and educational advantages, will

raise community standards and will make possible better fire protection, medical service and mail delivery in rural areas. Improvement of these local roads at this time will also give relief to unemployment. While the greatest number of unemployed are in the large centers of population, the situation is no less severe in many rural communities.

One of the present trends, which threatens seriously to affect highway development, is the diversion of funds derived from gasoline taxes and motor vehicle fees to purposes other than highway use. Due to the effects of the depression on state finances and as a result of legislative expediency, most of the states have taken large sums from motor vehicle revenues and have applied them to unemployment relief, to schools and to other purposes whose objects are equally worthy but as far removed from the purpose for which the taxes and fees were imposed.

The theory upon which the gasoline tax is based is sound and practical. The reason the gasoline enters the calculation is that it is easier to measure a motorist's use of the highways by the gasoline consumed than it is to measure his mileage. It is essentially a toll for road use that is collected at the gasoline station. When the gasoline tax was first imposed the highway users were promised that the revenue would be utilized for their benefit in highway improvement. As better roads mean lower vehicle operating costs, the motorists appreciated the fairness of the tax. Motorists now contend that diversion of the revenues from these special taxes to general purposes that should be borne equally by all citizens is unfair to highway users as a group.

In 1925 the total of state funds diverted to purposes other than highway improvement exceeded 14 million dollars. In 1933 the practice had become so wide-spread that the states diverted more than 124 million dollars that year or about nine times the amount so used in 1925.

Four states—Minnesota, Missouri, Kansas and Colorado—have adopted constitutional provisions which prevent use of gasoline tax and motor vehicle revenues in those states for other than highway purposes. Last year Congress, in appropriating highway funds to the states, placed itself on record as opposed to the practice of diversion of road funds by refusing to grant full federal aid to those states that do not continue to use at least the amounts that were provided by law for highway purposes at the time of the passage of the act.

It is evident that the highway funds diverted during recent years could have been used effectively in the betterment of our highway system by building a great many miles of modern roads, in eliminating a very large number of our more dangerous railroad grade crossings and in providing work for many thousands of our unemployed.

Experience of the past few years has demonstrated that road-building is one of the best means of providing jobs and at the same time performing a useful public work. The construction and maintenance of highways are operations consisting mainly of labor. Studies by the U. S. Bureau of Public Roads have established the fact that out of every dollar spent for highway construction 80 to 85 cents is ultimately paid to labor, directly or indirectly. Over 10 per cent. of the gainful workers in all occupations earn their livelihood due to our highway transportation system and its allied industries. Only one group, the agricultural, exceeds highway transportation in importance as a provider of jobs.

One of the recent trends in highway development has been advance planning by State Highway Departments of their future road work. These plans are

based upon state-wide traffic and economic surveys and are usually set up for a period of ten years. By anticipating the highway requirements of the next decade, the plan determines the improvements needed on the state highway system and the priority of their construction. The great advantage of advance planning lies in the fact that it establishes a definite and balanced program of road work based upon the anticipated needs and financial ability of the state and replaces the generally unplanned and uneconomical programs of the past, which were dictated largely by expediency and pressure brought from many sources.

Our highways, affecting each of us so vitally, are truly the arteries of the nation; upon them depends our national well-being. They carry to every section of our country the life-blood of agriculture, commerce and industry as well as social and educational advantages not enjoyed by the people of any other nation.

COLLECTING OLD HOUSES

By Dr. LAURENCE VAIL COLEMAN

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Collecting old houses is the perfect hobby. It takes the collector on trips, and yet never makes him carry a load of specimens, like a geologist, because he never tries to get his collection together in one place. This is convenient, too, because there is nothing to take care of.

The house-collector usually does his work with a car. He goes about the country whenever he has a chance, hunting up places he has heard of, watching for others to turn up, and often having another look at houses he already knows. He carries a camera and he takes notes, for he has a book in his head. He always makes friends with the people who live in the houses he sees, but he needs no introductions. There is brotherhood among people who love old houses, and the owner instantly takes the interested stranger in—going with him first to the attic, where the stranger bumps his head and breaks the ice.

A student of houses soon learns to tell the age of a house within a very few years. He can see the old structure as though its alterations were transparent. He gets to know houses as expressions of their times. If he is less than a student of history, he is not a house-collector, but a camera-snapper. If he does know his houses, a pageant of three centuries is spread before his eyes.

The story of dwellings in America should begin four hundred years ago, but there is nothing left of the very earliest houses. The abundant wood that nature gave to man for his use, she took back again through the work of insects, fire and rot. Therefore, we have not even a trace of Ribaut's Parris Island post, built in 1562 on the coast of South Carolina, or of the post built two years later in Florida by other Huguenots, or of Raleigh's famous Roanoke settlements in North Carolina, or of the outposts built in Maine by the French before the Pilgrims came.

Even our permanent colonies have left nothing to us from their very first years in the early part of the seventeenth century. The original shelters, both South and North, were made of sticks and branches laced together, daubed with mud and covered with thatch. The first cabins were made of poles stuck vertically into the earth around a floor dug half out of a hillside. The first frame houses were of two rooms, sometimes only one. They were half-timbered and

filled in with mud at the start, but later the frame was covered with boards to protect the mud, and then the mud was left out. This was how our present ideas of wood construction came about. Recently, Salem reconstructed a Puritan village, and there alone can we see likenesses of English colonial thatched houses, sod and bark huts, dugouts and construction of palisaded logs.

The oldest remaining house is the Fairbanks house of Dedham, Massachusetts—built in 1636 and amazingly well preserved. Sagged in frame and weathered in surface, with some of the old clay filling still in its walls, it is a document and looks the part. There are many houses from the middle seventeenth century in New England; and some of them, like the Henry Whitfield house in Guilford, Connecticut, are of stone. Rhode Island also has its old stone-enders with enormous fireplaces.

In Virginia, not a single frame house of the seventeenth century is left, but there are some brick houses from the middle of the century. The oldest is thought to be the Thoroughgood house at Lynnhaven. Famous Bacon's Castle is of slightly later date. Old Jamestown has only some foundations and the ruins of a church. Williamsburg, now so splendidly restored, is from the next century for the most part.

Houses of the seventeenth century were built by men who had learned their craft in England; who used medieval methods. Their work in America belonged to the middle ages. The earliest houses are Gothic. In the North, they are small but massive, with ponderous chimneys, steep gabled roofs, and sometimes with overhanging second stories, and casement windows with leaded panes. In the South, the houses are more slender. They have peaked dormers, and chimneys on the outside at each end. In the region of New York and Pennsylvania, nations of continental Europe established colonies and planted other traditions from the middle ages. The Dutch, coming after the Cavaliers of Virginia but before the Puritans of Massachusetts, built compact houses of masonry with white trim and dormer windows. The earliest have steep roofs; those of a little later, gambrel roofs with eaves extending to cover porches, back and front. The old town of Hurley, on the Hudson, still has houses of this kind. New York City once had them, too, but one can hardly find there the haunts of his boyhood, let alone the houses of the Dutch. In Penn's colony, also, masonry was adopted from the start in 1680. There English, German and Welsh colonists made separate settlements. The German stone houses had three stories, full of windows, and dormers and porch hoods. Welsh houses were much the same; but English houses included many of brick, like one still standing in Philadelphia's Fairmount Park.

About the year 1700 the classical style, born of the Renaissance in Europe, appeared in this country. After that, houses were built four-square, with two rooms on either side of a hall. They were higher than in the past, but the roofs were not so steep. And now cornices appeared. This was the beginning of distinguished doorways and mantels with ornamental pilasters and moldings, carved woodwork and modeled ceilings—features that we call colonial and that we now paint white, although colors were much used in those days. This modern whiteness is not surprising. Ghosts are always pallid. We build our Greek memorials now in dead white stone, though Greece made temples alive with color.

The American renaissance was prim at first, but by 1725 it loosened up a little and from that time until the Revolution came the Georgian houses—larger and more elaborate, with more carving around doors and mantels. We got the

ideas from English books, and any good amateur could then design a house. Many Georgian places are still standing along the coast—the Wentworth-Gardner house at Portsmouth, Mount Pleasant in Philadelphia's Colonial Chain of houses, and the Miles Brewton house at Charleston, among the best. The Dutch descendants had their Georgian house, too, like the Van Cortlandt house in New York.

During the years before the Revolution, the eastern towns began overflowing into what was then the West. Along the Appalachians, where those who wanted land could take it, the pioneers built log cabins of the kind we know to-day. They laid logs horizontally, joining them at the corners. This idea came from the Swedes who had settled in Delaware. The early cabins of New England and the South were never like this; they had logs set vertically like cigarettes in a pack.

During the eighteenth century, also, the French were settling scattered posts in the region of Detroit and Vincennes. A few of their houses have survived to show how they too set logs on end and chinked between with mud. Chicago has one of these cabins under a canopy in Jackson Park. The Louisiana region was settled during this same time. Following the lead of Biloxi, New Orleans grew up from a settlement of rude cabins of split cypress boards roofed with cypress bark. Later in the century fires swept everything away, but the Spaniards rebuilt the public square, and the French Creoles replaced dwellings in the old quarter, where there are still half-timbered houses with walls of sun-baked bricks, somewhat later in date but resembling what had gone before. Florida was building in the eighteenth century also, but when French, Spanish and English got through quarreling and various fires had been put out, there was nothing left of the beginnings. In the far Southwest, Spanish priests and soldiers, with Indians to work for them, built the early missions in the eighteenth century, and around them they built adobe cells to live in. The missions still survive.

After the Revolution, there was a classical revival in which Thomas Jefferson himself had an early hand as an amateur architect. By 1820 this revival had turned into the first American fad—building Greek temples. But soon industrialism captured the land, and people were so busy grabbing and exploiting that they stopped paying much attention to their houses. Flats appeared in cities, botchy houses covered with ornaments from the scroll saw and the turning lathe were put together with more haste than taste, and things that looked like packing boxes became the homes of the poor.

Then, after 1860, all sorts of revivals came along, and those who could afford it built anything from a Gothic castle to a mosque—to show who they were. From the French we adopted the mansard roofs, which had been invented to get around the Paris tax collector, who counted floors.

But out of all this in the end came a new and worthy architecture made possible by steel girders and elevators. This is a recent chapter of the story familiar to every one.

There are thousands of houses in every part of the country worthy of being saved because they are old or fine or representative. Some of them are called historic because they have held important people or seen great events. But all houses are really historic because they help to tell the story of America. Hundreds of them, mostly old, have been saved as historic house museums in the care of organizations. These, and many others that still are homes, are in my own collection of houses; and if you want them for yours, I give them to you.

THE WORLD DIGS UP ITS PAST

By Dr. HENRY RUSHTON FAIRCLOUGH

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"ARCHEOLOGY," says Flinders Petrie, "is the latest born of the sciences," and this science, as the same distinguished authority writes, "touches us more closely than any other," being one "which shows what man has been doing in all ages and under all conditions, which reveals his mind, his thoughts, his tastes, his feelings."

As a real science, conducted and controlled by true scientific methods and principles, archeology came into being within the lifetime of the present writer and possibly of many others who are his readers. To be sure, we are deeply indebted to the antiquarians of earlier days, and we should be very ungrateful if we forgot certain great figures of the past, such as Pliny the Roman, Pausanias the Greek, and Petrarch the Italian, all of whom loved to recall the triumphs of earlier civilizations. In the eighteenth century the famous Winckelmann for the first time applied historical principles to the study of ancient art, and he, therefore, is sometimes called the founder of archeological science.

It was in 1763, in the very year of the publication of Winckelmann's "History of Ancient Art," that excavations were begun on the site of the buried Italian city, Pompeii, and it was about twenty-five years earlier that an accidental discovery led to the partial excavation of the lost Herculaneum and to the recovery of so many of the beautiful marbles and bronzes that to-day embellish the great National Museum in Naples.

At the opening of the nineteenth century and during the Napoleonic wars, Lord Elgin carried off from Athens the famous "Marbles," which are to-day the most precious possession of the British Museum; and other important discoveries of Hellenic art were made at this time, in Sicily, Italy and Greece itself, such as that made by a small party of English and Germans of the sculptures in Aegina, which were later restored and set up in the newly erected Glytothek in Munich.

It was still treasure-hunting, though of an enlightened kind, that gave birth to the scientific approach and the scientific method in the field of archeology. The extraordinary story of Heinrich Schliemann is well known. Born in 1822 in a north German village of Mecklenburg, he served as a grocer's apprentice, started as a cabin-boy on a voyage to South America, was shipwrecked and tossed up on the Dutch coast, then found work in Amsterdam, where his industry and ability so commended him to his employers that they sent him as their agent to St. Petersburg. Here he afterwards began business on his own account, and laid the foundations of an enormous fortune. In 1850 he came to California to search for a brother's grave, which he found in Sacramento, and in May, 1851, he had a narrow escape from death in the San Francisco fire of that year. By reason of his presence in this state when California was admitted to the Union, he was proud of being able to claim American citizenship.

It was not until 1868 that Schliemann first set foot in Greece, but he had always nursed a romantic ideal. In childhood his imagination had been fired by a picture which showed Aeneas escaping

with his aged father and his little son from the flames of Troy, and then and there he made up his mind to look some day for the ruins of that famous city. This strange purpose was confirmed a few years later when one day he listened open-mouthed to a tipsy miller as he recited a long passage from the Iliad in Homer's sonorous Greek.

Scornful scholars laughed when in 1870 Schliemann began to dig for Troy in the mound of Hissarlik in Asia Minor. Eager to reach the lowest level, he made his way down in rough, slap-dash fashion, paying little heed to the upper strata, and by 1873 he had laid bare some fortifications and had unearthed a great treasure of gold. Not without reason did he then believe that here was Troy, and here the wealth of King Priam. As a matter of fact, he had dug too deep, and had reached a layer that must have antedated Homer's Troy by several centuries. Even the treasure, rich as it was, could not compare in value with the vast hoard of gold, silver, ivory and other precious objects which Schliemann was to find three years later at Mycenae—a collection since rivalled only by the magnificent contents of Tutankhamen's Tomb, which in 1923 Lord Carnarvon and Howard Carter brought to light in Egypt.

Schliemann's unexpected success was to bear fruit "an hundred-fold." It gave a tremendous impetus to archeological research and, in various lands, scholars who had been contemptuous or incredulous now turned from their loud scoffings to prayerful planning for other investigations, to be conducted, however, on more approved lines. In 1874 the German Institute at Athens was founded and in 1875 began its thorough excavation of Olympia. In 1877 the French started similar work at Delos, to be followed by their splendid excavation of Delphi. In 1879 the British established their Hellenic Society and shortly afterwards began to explore sites in the Peloponnesus. In the same year the Archaeological Institute of America was founded in Boston, and within two years began its first excavation at Assos in Asia Minor.

As to improvement in scientific method, this was well exemplified by one of Schliemann's own co-workers, for in 1891, the year after Schliemann's death, Wilhelm Dörpfeld, his architect, a man still living, who has been an inspiration to several generations of students, began a fresh investigation of the hill of Hissarlik on a more extended scale, and after examining it layer by layer discovered that there had been nine ancient settlements on the site. Of these the sixth corresponded most closely to Mycenae, and had the best claim to be regarded as Homeric. Dörpfeld's work in the Troad, and the excavations at Olympia and Delphi have served as models for all subsequent archeological investigations on a large scale, wherever conducted.

One of the immediate results of Schliemann's success was to focus attention upon the possibilities of research in the prehistoric field, and thus we can understand why, as soon as the island of Crete, as a result of the rebellion of 1897, was freed from the Turkish yoke, archeologists seized the opportunity to excavate in that famous cradle of Greek civilization. The remarkable discoveries made at Knossos by Sir Arthur Evans, followed by the Italians at Phaestos, the British at Palaekastro, and the Americans at Gournià, have entirely revolutionized our knowledge of the remote past of both the Greek world and the whole Mediterranean area.

How far this fresh interest extended at the opening of the twentieth century is well illustrated by the creation, on the part of the British Government, of the Archeological Survey of India. Under this one of our Stanford alumni, David Brainerd Spooner, served as superin-

tendent of the North-West Province, and in this position made a brilliant record. Not only did he fill his new museum at Peshawar with objects illustrative of the influence of Greece and Persia upon Indian art, but he also laid bare the site of a large temple built by a Greek architect for King Kanishka, and then he discovered at the very center of its foundation a crystal casket enclosed in bronze and containing human bones that have been officially recognized by Buddhists throughout the world as relics of Gautama Buddha himself.

In regard to Egypt, it was in 1880 that Sir Flinders Petrie, of London, began his excavations, while our best-known American Egyptologist, Dr. James Henry Breasted, of Chicago, entered on his work in that land in 1894. In Berlin eight years later, when I first met Dr. Breasted, he remarked to me that the history of Egypt was not yet written, though the material was accumulating very rapidly. Since then it is astonishing how much has been learned about that ancient land, and how much both Petrie and Breasted have contributed to our present abundant knowledge.

To-day, however, the center of interest in archeological research has passed from Egypt to Palestine, Mesopotamia and neighboring countries. Sir Flinders Petrie is now working in Syria, and the Oriental Institute, directed by Dr. Breasted, is conducting excavations at Persepolis, the ancient palace-city of Persia.

In Mesopotamia, under the changed conditions since the Great War, research has been carried on with the cooperation of English and American scholars, and two of the oldest cities in the world have thus been explored—Kish, said to be "the first city built after the flood," and Ur of the Chaldees, the birthplace of Abraham. The former was excavated by the Field Museum of Chicago and the University of Oxford; the latter by the British Museum and the University of Pennsylvania. The discoveries include records of the life lived by people between the Tigris and Euphrates six thousand years ago. And, even as I pen these lines, there comes the news that a scientific party from the University of Pennsylvania, digging in the same region, on a site where twenty ancient settlements lie buried one above another, has just reached the level of a town antedating Ur of the Chaldees by some 2,000 years.

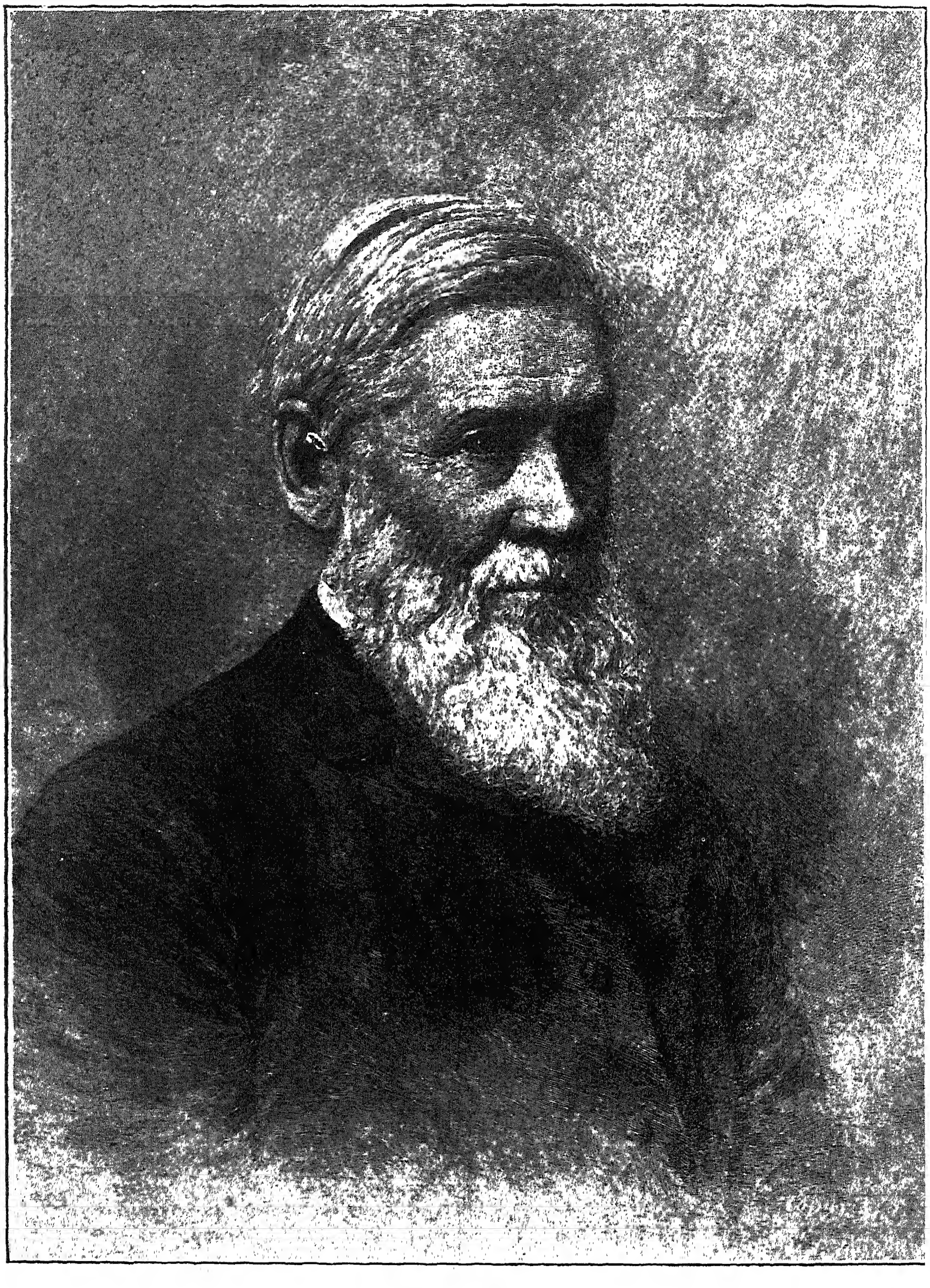
But it is in Palestine that archeologists are most active to-day. They are exploring ancient Biblical sites, such as Mizpah, where our own Dr. Badè, of the Pacific School of Religion, is still at work. And the most outstanding discovery yet made in Palestine is to be credited to another Californian, Theodore D. McCown, son of Dr. C. C. McCown, the present dean of the same school. In the spring of 1932 Mr. McCown, working under the joint auspices of the British School of Archaeology in Jerusalem and the American School of Prehistoric Research, had the great good fortune to find eight complete skeletons of human beings buried in the floors of caves at the foot of Mount Carmel. They are so completely embedded in the limestone breccia that it will take some years of careful work to detach them without injury. Judging from the bones of extinct animals found with them as well as from the rock itself, Sir Arthur Keith refers these skeletons (including a ninth, found by Miss Dorothy Garrod) to a period earlier than that of Neanderthal man in Europe, possibly 100,000 years ago.

These skeletal remains of man long antedate the Stone-Age paintings that have been found on either side of the Pyrenees. The first of these discoveries was made in the Altamira cave in Spain in 1879, and since then more than fifty similar caves in both Spain and France have yielded thousands of specimens of

a skilful pictorial art, which was contemporary with the existence in those countries of the reindeer and the bison, as well as of the mammoth and the woolly rhinoceros, animals now long extinct. These remarkable wall-and-ceiling paintings were produced at a time when man lived wholly by hunting and fishing and before he knew aught of the weaving art, of the building of huts, of the smelting of metals, of the taming of animals or of the tillage of the soil.

Space does not permit me to make more than a brief reference to that field of archeology which to many of us is the most attractive, because it lies, as it were, before our very doors. It is now generally conceded that America was a manless world until human beings passed from Asia across the Behring Strait and thus spread throughout this continent. When such a migration first took place is not known, but Dr. Hrdlička, probably our most outstanding anthropologist, would place the event not more than five or six thousand years ago. The many native cultures that have been developed in America since then include the Pueblo, the Mayan, the Aztec and the Inca, which have left so many interesting and imposing evidences. In the discovery and study of these many of our universities and museums are now engaged, and along with them certain foundations, such as the School of American Research at Sante Fe, New Mexico, one of the latest-born children of the Archaeological Institute of America.

With all the modern facilities for research, no wonder that many of our college students are attracted to the pursuit of archeology, for not only is it the youngest of the sciences, but it is also one of the most fascinating, dealing as it does with the past life of man in all parts of the world from the very infancy of the race.



ASA GRAY

THE PROGRESS OF SCIENCE

BOTANY AT HARVARD UNIVERSITY

A very few educational institutions at home and abroad have single separately endowed botanical units, such as herbaria, arboreta and gardens, but Harvard University has the unique distinction of controlling eight separately endowed units within the general field of botany. It is these quasi-independent units that have given the university the outstanding international prestige that it commands in this field of science, for much of the productive work of several of them has been distinctly of international scope.

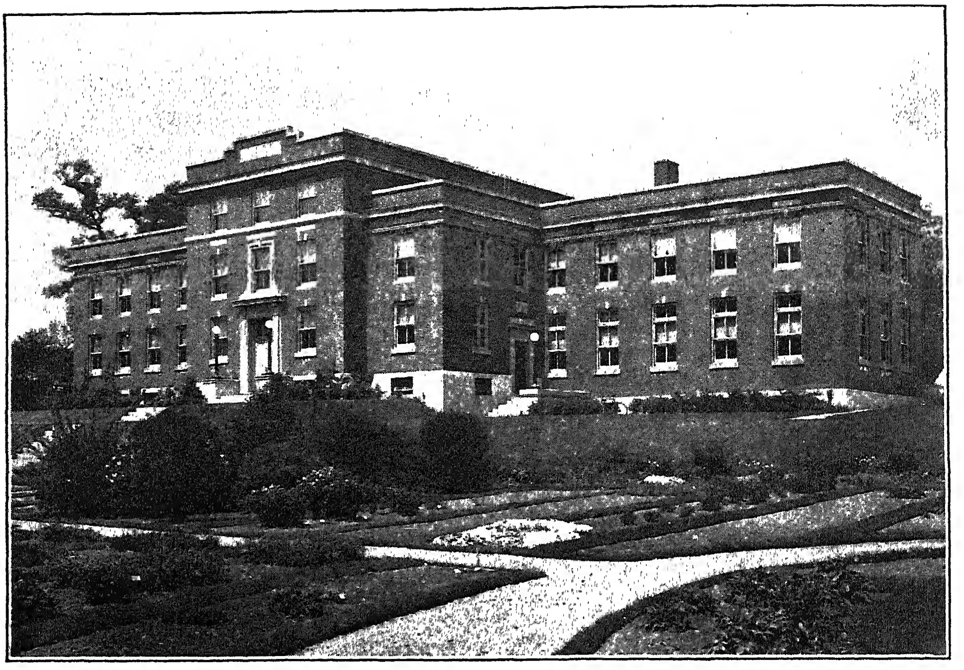
These separate institutions, all a part of the university, and, to a certain degree, their destinies controlled by it, are independent of each other, yet all are cooperating in botanical research. They have been established over a long term of years, in some cases on the basis of bequests to the university for specified purposes, in other cases due to the interest and ability of individual members of its staff who utilized their own funds for establishing and maintaining activities in which they were interested, or who secured their support from individuals that they interested in their projects. Among the institutions established on the basis of initial endowments are the Bussey Institution, the Arnold Arboretum (in the case of the latter its resources tremendously increased by its first director) and the Atkins Institution. Among those that were actually established by individual members of the university staff are the Gray Herbarium, the Farlow Herbarium and Library, the Harvard Forest and the Botanical Museum. The eighth independent unit, the Botanic Garden, the oldest of all of them, was gradually developed over a long term of years as an adjunct to the teaching of botany.

These units are, to a considerable degree, independent of the teaching activities of the university, yet many of their staff members offer courses and direct graduate work. Supported entirely by the university and independent of the eight separately endowed units is the magnificent Biological Laboratory, wherein is combined in a single Department of Biology the actual teaching and various phases of laboratory research in botany, zoology and general physiology.

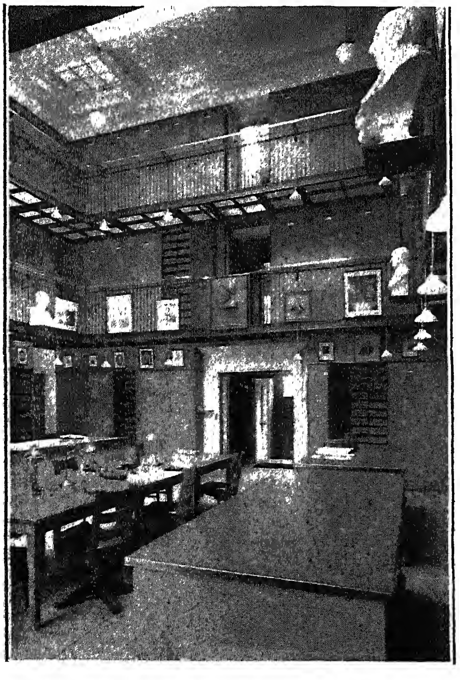
Because of the historical development of the independent units there naturally has developed a considerable amount of duplication in equipment, in reference collections and in library facilities. In fact, Harvard University maintains three of the largest, most comprehensive and most valuable botanical libraries in America and three great herbaria, all rich in historical material. Their combined resources in historical reference material are unequalled in America and are exceeded only in a very few of the older institutions in Europe.

The Bussey Institution, originally developed for instruction and research in agriculture, has contributed its quota to the development of the biological sciences in America. Its resources to-day are largely utilized to support fundamental investigations in genetics, work being prosecuted in both the plant and animal fields.

The Gray Herbarium, established and developed by Dr. Asa Gray, America's greatest botanist, represents his life work as an outstanding authority on the North American flora. It officially became the property of the university in 1864 when Dr. Gray presented it to Harvard College, yet he continued to add to it until his death in 1888. Through the efforts of his successors,



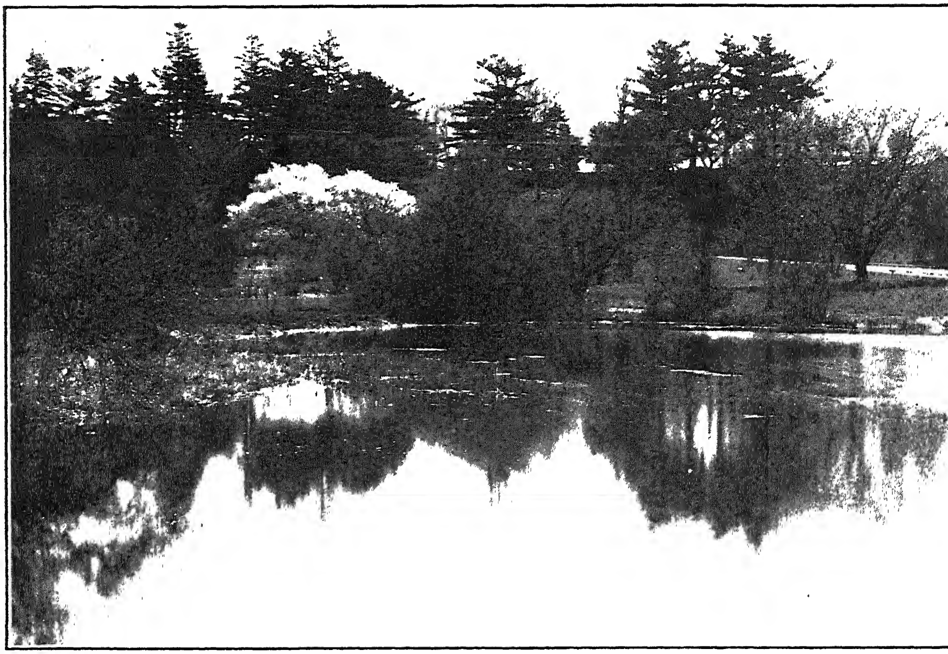
THE GRAY HERBARIUM OF HARVARD UNIVERSITY



A ROOM IN THE GRAY HERBARIUM

Sereno Watson and the late Dr. B. L. Robinson, supported by friends of the institution, its resources were greatly increased. Its reference collections now contain approximatley 900,000 sheets, a magnificent library of nearly 30,000 volumes and over 17,000 pamphlets, housed in a specially constructed fireproof building, a model of its kind. As a taxonomic institution, it is the most widely known one of its kind in America and annually attracts numerous students and investigators because of its unique stores of historical material.

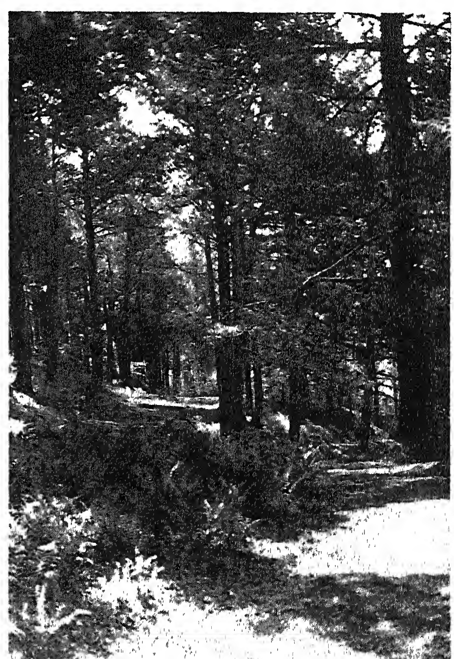
The Arnold Arboretum, the most widely known institution of its kind in the world, owes its existence to a bequest from James Arnold which became available to the university in 1872. It had been stipulated that only one third of the income from this fund could be used until the capital had increased to $150,000, so its initial income, until about ten years later, was but about



A POND SCENE IN THE ARNOLD ARBORETUM

$3,000 per year. The magnificent development of the institution, with its 250 acres of diversified plantings, its great library, approximating 43,000 volumes, and its comprehensive reference collections of living and herbarium material, and the commanding position that it occupies in the botanical and horticultural world is due in very large degree to the ability, support, initiative and persistence of its first director, Charles Sprague Sargent. Its material resources have been very materially increased since Sargent's death in 1927 under the leadership of Professor Oakes Ames. In contrast to the Gray Herbarium, as to taxonomic research, its field has been largely in eastern Asia, that of the Gray Herbarium largely North and South America.

The Farlow Library and Herbarium, bequeathed to the university by Professor W. G. Farlow, represents his lifetime's work in assembling a great cryptogamic herbarium and the comprehensive



HEMLOCK HILL IN THE ARBORETUM

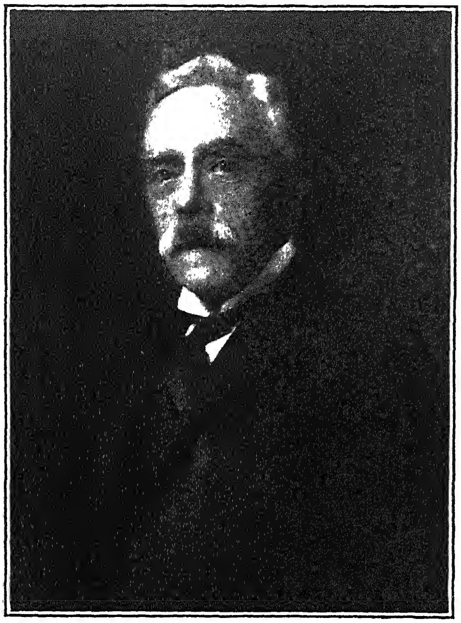
library facilities essential to its proper use. It now contains in excess of 850,000 specimens of fungi, algae, lichens, mosses and scale mosses and is noteworthy for the historical collections acquired from time to time. It is especially rich in type collections. Its library facilities are equally remarkable, somewhat in excess of 30,000 volumes.

The Botanical Museum was established in its present form in 1890, although a so-called museum had been initiated as early as 1858. Its development was the work of Professor G. L. Goodale, continued by Professor Oakes Ames. It is noteworthy for its magnificent Ware collection of glass flowers, the artifacts being the highly skilled, artistic and equally accurate work of Leopold and Rudolph Blaschka. No botanical exhibit in any other existing public or private institution anywhere in the world compares with this in attractiveness and in its appeal to the public, special visitors exceeding 200,000 each year, the number constantly increasing. The museum also contains unique and comprehensive exhibits of the economic products of the plant kingdom, the crude products, displayed in association with the finished products, indicative of their application in the arts, sciences and industry.

The Harvard Forest at Petersham, Mass., comprises approximately 2,500 acres. Its establishment and rather remarkable contributions to the profession of forestry was due to the interest and initiative of the late Professor R. T. Fischer. In its acquirement, development and endowment the objectives were the maintenance of a model forest for the demonstration of various phases of applied forestry without depletion of capital, practical and fundamental investigations in forestry and a great out-of-doors laboratory wherein forestry biology could be effectively studied. Actual instruction in forestry is confined to graduate work.

The Atkins Institution of the Arnold Arboretum at Soledad, Cienfuegos, Cuba, was established by the late Edwin F. Atkins, the work first undertaken there being sugar-cane breeding investigations. Gradually the development took the form of a comprehensive tropical botanical garden, with equipment and living quarters available for visiting biologists. The present area comprises about 300 acres, of which approximately 200 acres are

TROPICAL PLANTS AT THE ATKINS INSTITUTION IN CUBA



W. G. FARLOW

Portrait by John Singer Sargent, 1919
CHARLES SPRAGUE SARGENT

developed and planted. This forms a magnificent tropical base for biological investigations, and it will become increasingly useful in this field as the institution is developed. Its use by graduate students and investigators is increasing rapidly and demands for an opportunity of visiting it and working there exceed the scholarships available for this purpose. It is becoming increasingly evident that all biologists greatly benefit from an opportunity to carry on investigations under tropical conditions, and Harvard University is indeed fortunate in controlling, as it does, this tropical base.

The modern magnificently equipped, commodious Biological Laboratory was constructed in 1931–32. In it is located the Department of Biology, consisting of botany, zoology and general physiology combined, covering various phases of laboratory research, as well as undergraduate and graduate instruction. The construction of this building enabled the university to reorganize its entire biological set-up and to establish a large and very important unit, based on research, comprising all available university groups in the biological field and including various staff members from the several independently endowed units.

The combined resources and output of these numerous units within the general field of botany has resulted in great prestige to Harvard University. It was with the hope that the productive output could be increased and further developed that the position of administrator of botanical collections was recently established at the university. One of the objectives is to further coordinate the work of the independent units, eliminate duplication as far as possible or desirable, encourage cooperation and to develop still further fields of research.

ELMER D. MERRILL
ADMINISTRATOR OF BOTANICAL COLLECTIONS
HARVARD UNIVERSITY


HAYDEN PLANETARIUM

A PLANETARIUM FOR NEW YORK

To the skyscraper city where smoke, haze and bright lights obscure the stars, the Planetarium brings clear skies for every day of the year. All the stars visible to the naked eye, the sun, the moon and the planets may be shown by the Zeiss Projection Instrument recently presented by Charles Hayden to the American Museum of Natural History. Housed in a new wing built with RFC funds, the New York Planetarium was opened to the public on October 3.

The projection planetarium was devised by Carl Zeiss engineers in Jena, and the first was installed in the Deutsches Museum of Munich in 1925. In the ten years since then, twenty-one such planetaria have emanated from the factory in Jena and so far the monopoly of their manufacture remains there. The intricacy of the design of these ingenious machines is an even greater protection than the patents on their many unique features.

Of course countless planetaria had preceded the Zeiss model, but nearly all these represented the sun and the planets as they would appear to an observer in space—not as they are seen in the sky by an observer on the earth. Such devices had shown the solar system by means of models; the new instrument employs a new principle—that of projection.

Hung on a carriage which achieves the maximum of strength with the minimum of structure, the giant stereopticon resembles a dumb-bell. Knobs at each end carry the naked-eye stars, one globe for the northern hemisphere, one for the southern. In all, the 9,000 stars visible to the best eyes under the most favorable conditions are shown by light passed through 32 minutely perforated sheets of copper. These are essentially lantern slides, the projected images of which fit together like the cells of a honeycomb and completely cover the artificial sky dome overhead. So perfect are the images in relative brilliance and position that the illusion of space is unbelievably real and the crispness of the night air is almost sensible beneath the blueness of the night sky. So breathtakingly beautiful are the starry heavens that their first appearance, accompanied by music, never fails to draw a gasp of wonder from the audience.

To produce the rising and setting of the stars, the instrument is driven by motors about its polar axis. Speeds of 10 and 4, 3 and 1 minutes and their combinations (made possible by planetary gearing) may be used for this diurnal motion. To prevent the setting stars from passing across the faces of the audience and over the floor, each lens is equipped with a self-adjusting gravity "eyelid" which automatically shuts off the light of the stars as they reach the horizon.

Rheostatic control of the horizon light as well as that of the sun makes it possible to simulate the dawn with great reality, especially since the sun's projector also carries a diffuse halo.

The planets are represented as they appear in a small telescope so that they may be more easily distinguished from each other and from the stars among which they trace their paths. The apparent annual journey of the planets and the sun may be run through in 4 minutes, 1 minute and 7 seconds, or their combinations. Any daily motion adds its proper increment to the annual motion which, in turn, adds a still smaller progression to the precessional motion. At any of these speeds, the moon provides comic relief with its fleeting phases.

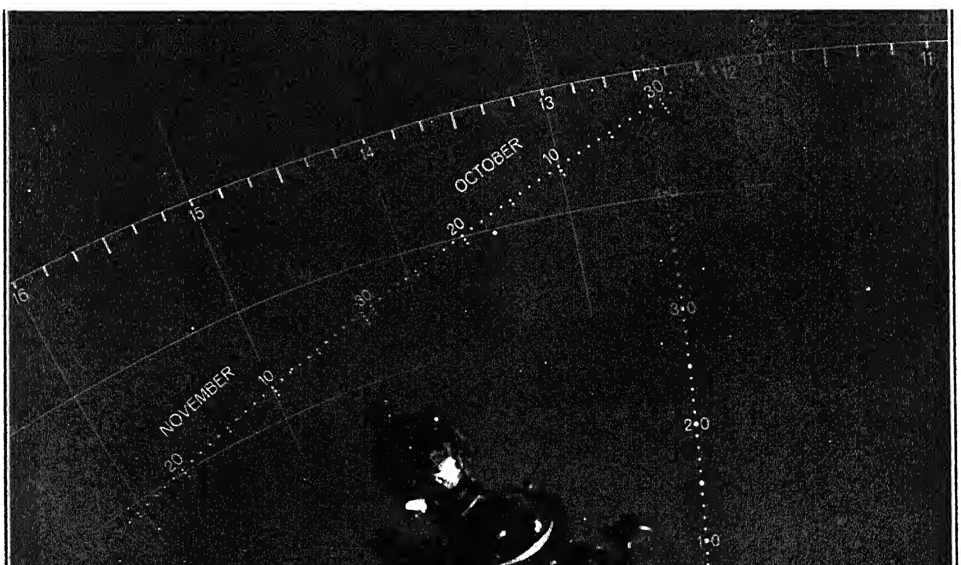
In all the foregoing respects the instrument in the New York Planetarium is very similar to the other Zeiss projectors, but it has several unique features. A "mean Sun," that imaginary timekeeper which does not actually exist, can

appear in the planetarium sky alongside the real sun. The mythological characters of the ancients boldly outline the constellation figures when the new accessory projector is used. The famous Donati's comet arches its filmy tail across the skies in a path identical to that which it followed in 1858 as the motion picture attachment projects its passage. Leo, overhead, showers the surrounding regions with shooting stars as an ingenious device allows light to pass through slits which rotate and fall by means of a spiral shutter.

Up in the polar regions the midnight sun circles near the horizon. For although the machine is anchored in place, by turning on its horizontal axis it can transport its watchers not only in time but also in space. Or perhaps later in the same region, dancing streamers of the northern lights appear and weave their pattern against the black of the arctic night.

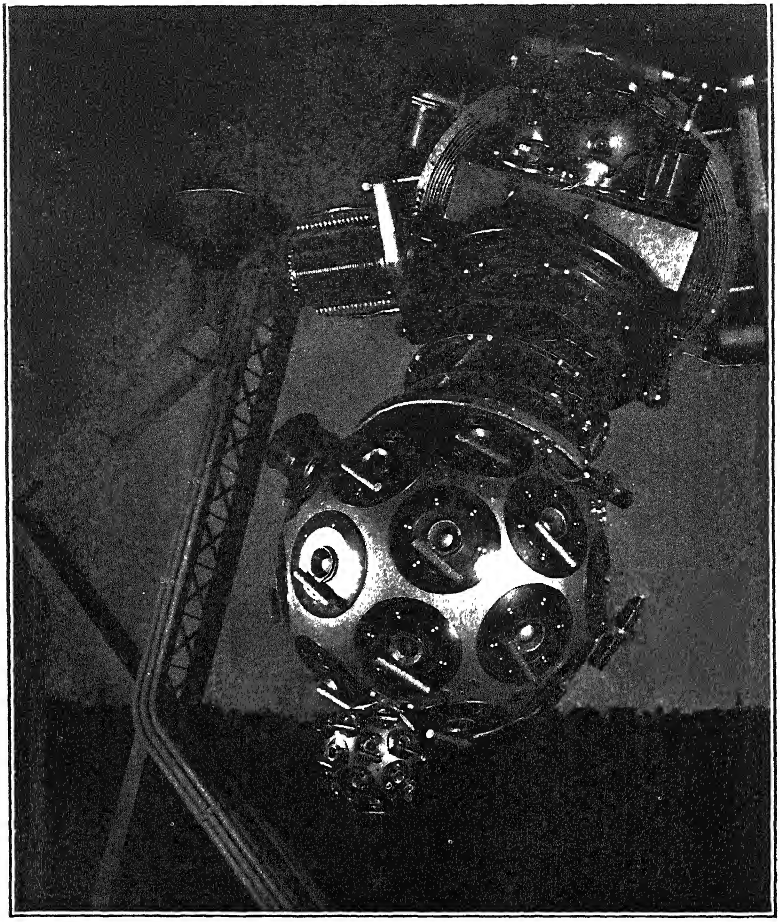
All these wonders occur within a room but seventy-five feet in diameter and are repeated frequently for the group of 750 watchers which the chamber will accommodate. The room itself is interesting, for its domed ceiling is a stainless steel shell just one sixteenth of an inch in thickness. It is painted white for reflection of light and perforated with millions of holes for the passage of sound. The perforations, the space between the inner and outer domes and the corklining to the outer dome all help to make an almost echoless chamber.

From the base of the steel sky is cut in silhouette the skyline of New York. Made from panoramic photographs taken in infra-red light just inside Cen-



THE PLANETARIUM INSTRUMENT

WITH THE STARS AND THE SKY MARKERS WHICH IT PROJECTS ABOVE THE ARTIFICIAL NEW YORK SKYLINE.



THE PROJECTION INSTRUMENT AGAINST THE SKYLINE

tral Park near the museum, it shows the museum to the west, the buildings of Fifth Avenue to the east, the trees of the park to the north, and the downtown spires to the south, with the Chrysler Building, Radio City and the Empire State Building prominent among them. The buildings of this skyline are never clouded from view by either haze or bright lights and above them the stars sparkle nightly in a cloudless sky.

In a circular room directly beneath the projection chamber is another type of planetarium in which the solar system is represented in three dimensions. Models of the six planets nearest the sun move about it at their correct relative speeds with their satellites in attendance. The planets' paths are seen against the stars of the zodiac which surround the room in the mythological figures from Bayers "Uranometria" of 1603. The Calendar stone of the Aztecs has been reproduced in the floor of the room in a marble mosaic. This largest Copernican Planetarium in the world is forty feet in diameter and, although it resembles one in Munich, was designed by telescope-maker J. W. Fecker especially for the Hayden Planetarium.

DOROTHY A. BENNETT
THE HAYDEN PLANETARIUM

THE CONTROL OF OYSTER PESTS BY THE UNITED STATES BUREAU OF FISHERIES

Believing that the oyster grower is entitled to protection equally with the farmer, the United States, by a special act of Congress, has appropriated one hundred thousand dollars for the study of marine animals destructive to oysters. The annual losses caused to the oyster growers have amounted to many millions of dollars, and in Florida they have lately caused complete destruction of valuable bottoms and the subsequent loss of jobs to hundreds of people. The U. S. Bureau of Fisheries, under the leadership of Commissioner Frank T. Bell, is now working on this large project on the conservation of the national marine resources in our inshore waters. The results of the work will be of benefit to the thousands of people whose livelihood is entirely dependent on the products of the sea.

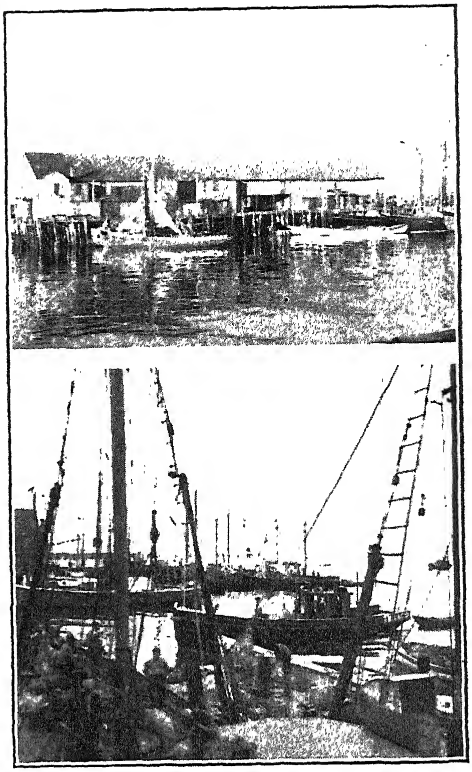
A sudden outburst of a rather innocent-looking planarian, locally called the "leech," which in 1932 destroyed over a thousand acres of oyster-producing bottoms in Apalachicola Bay, Florida, was responsible for the inauguration of this comprehensive research program, which includes also the studies of the distribution, life histories, migrations, destructiveness and methods of control of other oyster pests, namely, the starfish, drills, conchs, boring clams and boring sponge.

Under the direction of Dr. Paul S. Galtsoff the work is being carried on along the whole coastline from Cape Cod to the mouth of the Rio Grande, and is divided into five major projects which, in general, coincide with the distribution of the enemies of the oyster. A large number of zoologists are contributing to the success of the project and all the coastal states are cooperating in the research work.

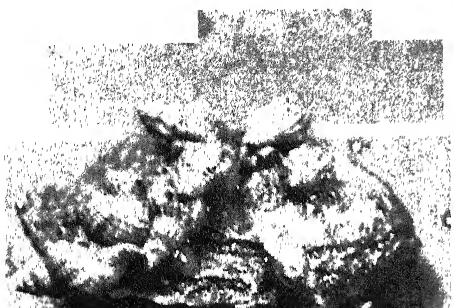
Of all the enemies of the oyster, the control of the "leech" presents the greatest difficulty, for the life history of this organism is unknown to science. In order to carry out this investigation, it became necessary to construct a laboratory at Indian Pass, eighteen miles from Apalachicola, Florida. The work, in charge of Dr. A. S. Pearse, of Duke University, began early in April and so far has produced interesting results, showing the habits of this worm, methods of propagation and its reaction to the environment. Besides the leech, a borer and a boring clam are the important enemies of the oyster in the Gulf of Mexico waters which are being studied by a staff of four scientists stationed at Apalachicola.

In the south Atlantic and middle Atlantic states, the work comprises a study of the tropisms and method of propagation of the two species of snails—Urosalpinx and Eupleura, which destroy oysters by drilling small holes in the oyster shell and sucking the meat. Altogether, sixteen persons are at present engaged in this work carried on under the direction of Dr. H. F. Prytherch, with headquarters at the U. S. Bureau of Fisheries station at Beaufort, North Carolina. The snails have a tendency to climb over any object on the bottom of the sea; this negative geotropism has been utilized for developing a method of trapping, which consists in placing wire bags filled with shells over the oyster bottom. Thanks to the cooperation of the Federal Relief Administration, 150 laborers were assigned to the project and, under the supervision of scientists, are engaged in large-scale field experimentation which provides very interesting data, showing the relationship between the behavior, growth, rate of propagation of the snail and its environment. To show the magnitude of this work, it suffices to mention that during this summer more than ten thousand traps were set in different localities and yielded about three quarters of a million drills. A mass of biological and ecological material has been assembled and is being analyzed. Similar work is being

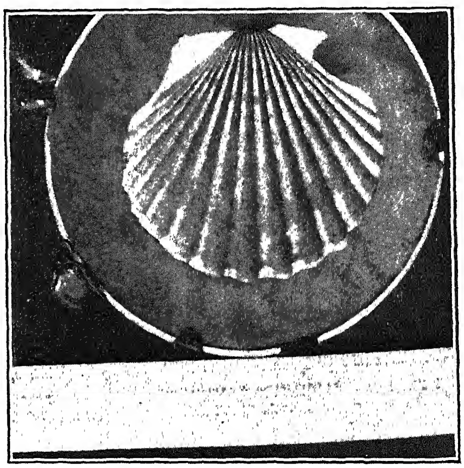
DR. PAUL S. GALTSOFF
DIRECTOR OF THE OYSTER PEST CONTROL PROJECT OF THE UNITED STATES BUREAU OF FISHERIES.



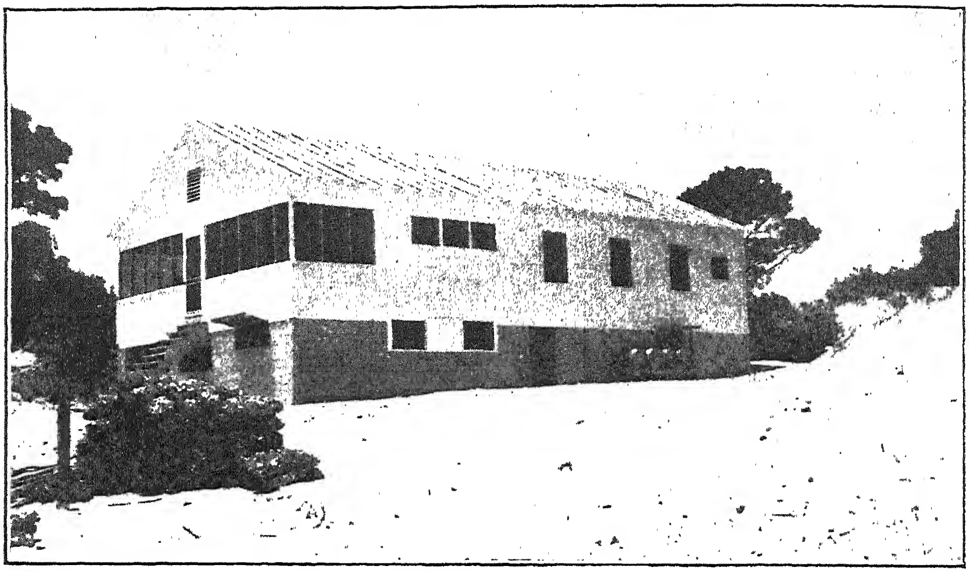
FISHING BOATS AT PROVINCETOWN



DRILLS BORING IN OYSTER SHELL
SO THEY MAY SUCK THE MEAT OF THE OYSTER.



SCALLOP KILLED BY OYSTER DRILL
SEE TWO HOLES IN THE EDGE OF THE SHELL.



THE LABORATORY OF THE UNITED STATES BUREAU OF FISHERIES AT INDIAN PASS, APALACHICOLA, FLORIDA

carried out in Delaware Bay under the direction of Professor Thurlow C. Nelson, of Rutgers University.

The work in the northern states is conducted by Dr. Galtsoff from the U. S. Bureau of Fisheries station at Woods Hole and by Mr. V. L. Loosanoff at the field laboratory at Milford, Connecticut. Eighteen scientists were employed during this past summer to study the life history, behavior, tropisms, development and migration of starfish. Comprehensive surveys, each lasting about three weeks, were made in Long Island Sound, Narragansett Bay and Buzzards Bay. They yielded interesting observations, showing concentrations of this animal in certain regions, its movements in relation to changes in the environment and supplied a large number of data essential for the development of a comprehensive method of control.

Experiments carried out at the shore laboratories were designed to throw some light on the factors controlling the life of the starfish. In order to study their migration, a method has been developed whereby the starfish is stained blue and released in the desired locality. The distinct coloration persists for several weeks and, not being harmful to the organism, permits the identification and tracing of its movements. Over 25,000 stars have been stained already and are under observation in the waters of Long Island Sound. In some of the experiments it has been observed that the starfish moved about twenty-five feet a day.

Carried out on a large and comprehensive scale, the oyster pest control project is yielding valuable biological data upon which sound methods of conservation can be based. It is the first time in the history of marine biology that the zoologists have been called upon to conduct large-scale field experiments that combine the results of field observations with laboratory data. Information gathered so far will be of great value, not only to the immediate problems of the control of pests, but will also contribute to the better understanding of the ecological conditions governing marine life of our inshore waters. Furthermore, at present the project brings relief to a great number of professional biologists who would otherwise have remained unemployed.

THE SCIENTIFIC MONTHLY

DECEMBER, 1935

SEEING THE INVISIBLE

By Dr. WALTER CLARK

EASTMAN KODAK COMPANY, ROCHESTER, N. Y.

THE adage which runs, "What the eye can't see, the heart doesn't long for," probably has proved a consoling thought to husbands whose ladies have engaged in Christmas shopping. It does not appear, however, in the phrase book of the scientist, whose great delight is to probe into and explain those things which are not obvious to his normal senses. It has been said that it is the spirit of man brooding over the stream of natural events that has given birth to science. Philosophers may argue as to whether the object of science is to explain these events of nature or merely to describe them. It is certain we should not get far in the explanation or the description if we confined our interest to those observations which we could make with the unaided eye.

For an explorer, delving into the exciting evidences of the glorious Maya civilization in the little republic of Honduras, it would be a relatively simple task to dissect the structure of one of the buildings of the old city of Copan. He would examine its external form, perhaps glorying in the beauty of its carving, and appreciate the shape and the nature of the stone blocks of which it was constructed, and learn much of the way in which they were put together. He could find out all these things by simple examination.

But suppose he were given a diamond and asked, "Please tell me how this is made"—his task would not be so easy. He would see that it was a transparent thing of beauty, its many man-shaped facets glistening in the light. But he would see little more; of its architecture he would learn nothing. His eyes could not peer into its interior and tell of its structure, of the "bricks and rafters" which went to make it the cold, hard beauty that it is. He would have to use other means more delicate than his eyes. The chemist could tell him that it was made of carbon, another form of coke, but if he wished to find out how these "bricks" of carbon were arranged he would need to use invisible x-rays. The eye, marvelous organ that it is, enabling us to see the grosser forms of objects and their colors, can not probe the deeper mysteries of matter and tell us why these objects have their shapes, and why they are so beautifully colored. The eye is relatively an insensitive thing, responding only to a very narrow range of waves in the wide gamut extending from the short cosmic rays to the long waves of radio.

Light is the messenger of the universe, bringing us the news, telling us of the existence of things, but betraying little of their inmost forms. For, the waves of light are long compared with the simple bricks, the atoms of which coarser things are made. And so we must resort to the shorter waves of x-rays, which compare in size with the atoms of matter. They

can penetrate the most opaque of things, and reveal their invisible construction. Instead of the eye, we use the photographic film, which is to x-rays what the eye is to light. The film extends our range of vision.

The marvels of to-day become the commonplaces of to-morrow. It is only thirty years since x-rays were discovered. They are now the indispensable tool of the scientist, engineer, the dentist and the surgeon. Incipient pyorrhoea, a fractured bone, a faulty casting, all reveal themselves before the penetrating rays. They are used in checking materials employed in the construction of large engineering works, machinery of transport, the construction of complex appliances inside an opaque housing, and in countless other engineering projects. Prior to the use of x-rays, faulty structures did not show their presence until failure of the defective parts occurred, resulting sometimes in loss of life. But nowadays there is little excuse for this. The value of x-rays to humanity is untold. They have been of great benefit in diagnosing tuberculosis in its early stages, and many other maladies with which man is afflicted. They have, further, revealed to the scientist the finest architecture of the simple crystals, as of salt or diamond, and the very complex structure of the felspars, of which much of our rock is made; they have shown the rearrangement of molecules which occurs when a rubber band is stretched and which gives it its elastic properties. Slowly, all materials give way before their ken.

Even more penetrating than the x-rays are the shorter so-called gamma rays of radium; these will penetrate as much as fifteen inches of steel, compared with a few inches in the case of x-rays. No apparatus is required to generate the gamma rays. They are as the life blood of radium, seeping away irrepressibly, draining it ultimately to its death. X-rays, on the other hand, require very elaborate electrical apparatus for their production. Still shorter than the gamma rays are the cosmic rays, the most penetrating we know. So far, scientists have not been able to produce or harness them, but who knows but that one day we shall convert them to our use, and what they will reveal?

But there is no need to go as far as the short x-rays to extend our range of vision. Close to the visible spectrum, just outside the range of our eyes, are the ultra-violet and the infra-red. The one, shorter in wave-length than the visible violet, is well known for its health-giving influence, in the form of the violet ray; the other, just beyond the visible red and merging into the heat waves, is used in thermal treatment when it is desired to warm up the muscles beneath the skin.

Through the microscope, the ultra-violet has shown the detailed structure of minute objects which pass unobserved when examined by visible light. It has shown the botanist that the surface of a leaf is a thin layer which absorbs very strongly, preventing entry of the short rays to damage the delicate cells beneath. It has revealed details of the cells of living matter, the minute structure of diatoms and many particulars which can not be resolved in the microscope by the longer visible light. In some extraordinarily fine work, Dr. F. F. Lucas, of the Bell Telephone Laboratories, has applied ultra-violet and blue light with a special microscope objective of unusually high aperture to the study of the structure of metals and alloys. He has photographed isolated particles which are only 200 to 300 atom diameters in size. The results have proved of great importance in the understanding of the function of heat treatment in the hardening of alloys, such as the chrome irons.

With the aid of ultra-violet photography the examiner of questioned documents becomes the despair of the forger, for he is enabled to detect the smallest

changes and to lay bare the falsifications of the most careful of criminals. The ultra-violet has also enabled the historian to reveal the original writing on palimpsests—old parchment sheets from which early writing had been removed so as to provide fresh surfaces for the pens of monks before the invention of printing—and to help the connoisseur of art to determine the authenticity of paintings concerning which there may have been some doubt.

More recently, there has been a growing interest in the study of the infra-red. This has been made possible by the discovery in the past few years of a remarkable series of dyes which can make the photographic film or plate respond to these invisible rays. Already, results of great interest have been obtained with their use. Three years ago the astronomers at Mount Wilson Observatory, using infra-red photography in the spectrograph, thought they had discovered the presence of the gas carbon dioxide gas in the atmosphere of Venus. They have now been able to show quite definitely that the planet's atmosphere contains very large quantities of the gas. The evening star is in reality a very gloomy planet. It is perpetually shrouded in a fog-like layer which has not so far been pierced. The surface of the planet has never been seen. But in the upper layers alone of its atmosphere there is about 10,000 times as much carbon dioxide as is present in the entire atmosphere of the earth. Moreover, there seems to be very little oxygen present around the planet. These facts, together with the absence of sunlight due to the shroud of clouds, indicate that there is no life, not even plant life, on its surface.

Towards the end of 1932, the planet Mars approached the earth and during the spring of 1933 it started receding, and the astronomers made an attack on it using new plates which photographic science had provided. They were interested to find out more about the constitution of its atmosphere. Without a knowledge of this, it is not possible to be sure about the opinions as to the nature of the planet's surface, nor to confirm or refute the views that there is life on it. It had long been thought that there was an atmosphere around Mars and that the atmosphere contained oxygen, essential for the support of life as we know it. Measurements now made have asserted definitely that if there is oxygen in the atmosphere of Mars, there is not more than one quarter of one per cent. of that present in the atmosphere of the earth. Such an amount could not support life of the higher forms with which we are acquainted. Is it that, after all, there is no life on Mars? Or is it a form of life which is adapted to conditions under which few living things could exist on earth? Much of the glamor of Mars has gone. Novelists can no longer thrill us with stories of Martian man, large of head and of superior intelligence. Clouds on Mars are very rare and its surface can be directly seen in the telescope. It has a desert-like appearance, and it has been suggested that oxygen, once present, has been exhausted in oxidizing the surface materials. The reddish hue of much of its surface may be due to iron oxide formed in this way.

Study of the planets more distant and less bright than Venus and Mars, although more difficult to carry out, has given results none the less startling, for in the atmospheres of these giant, cold planets has been found fairly certain evidence of the existence of the gases ammonia and methane—also discovered in the spectrograph—the former at Mount Wilson and the second at Lowell Observatory. Here is a problem for astronomer and chemist, and a rather curious one. Ammonia is a very reactive gas, consisting of nitrogen saturated with hydrogen; methane, less reactive than ammonia, and familiar as "marsh gas," consists of carbon saturated with

hydrogen. Both gases are stable. It is possible that collisions of atoms in the atmospheres of the planets have continued over vast periods of time, until eventually these most stable constituents have survived. It has been suggested that methane and ammonia are just the gases which would be expected to form if a mass of gas, having a composition like the atmosphere of the sun, were allowed to cool slowly to a very low temperature.

But the study of the infra-red has proved of great interest in very mundane things. If we gaze across the country in the direction in which we know lies a range of hills, say, forty miles away, we may not be able to see the hills at all. On some very clear days they will stand out on the skyline, steel blue with haze. On other days the haze will completely block them from our sight. The atmosphere always contains water vapor, and if this forms minute droplets on particles of dust or ions of gas which are usually present in the air, we have the appearance of haze. If the particles of moisture are bigger the haze thickens into mist or fog; our range of vision is cut down, and the outlines of distant objects are blurred, as if we were viewing them through a window of frosted glass. For these particles of moisture scatter light, just as the droplets of fat in milk scatter light, causing a turbid appearance. But they do not scatter light of all colors equally. If we view a street lamp or the sun through a haze or mist, it has an orange or red appearance, but may still appear quite sharp. This is because mist does not scatter red light nearly as effectively as it does blue or green. So that when we see the sun through a mist, the blue and green parts of the visible white light are scattered away and only the red gets through directly to our eyes. The further we get away from the blue in the spectrum, the more readily is the light transmitted by the mist, until when we reach the invisible infra-red just beyond the red end of the spectrum, it may not be scattered at all, but be transmitted quite freely.

So, if we wished to see distant objects clearly through a mist, we should do best if we could use infra-red rays. Unfortunately our eyes are not sensitive to these rays. We can, however, fall back on that substitute for the human eye, the photographic camera, and if we confine our exposures to the infra-red we can extend our range of vision and record our pictures clearly. Some exceedingly interesting results have been obtained in this way by a member of the crew of the 1934 stratosphere balloon, Captain A. W. Stevens, of the U. S. Army Air Corps, flying a plane in the region of the Andes in South America and in the direction of the Rocky Mountains in this hemisphere. In 1931, Captain Stevens, from a distance of 310 miles, photographed the peak of Aconcagua in the Andes. The mountain, of course, was quite invisible to the photographer's eye, and in order to ensure getting it in his picture he had to orient his camera by compass. This photograph excited a lot of interest because it showed the line of haze over the Pampas as curved, owing to the curvature of the earth—the first time that this had been photographed. Somewhat later, in 1932, Captain Stevens photographed objects at still greater distances, the subject of particular interest being Mount Shasta, which was no less than 331 miles from the camera. There is really no limit to the distance over which objects can now be photographed, except that imposed by their size and by the curvature of the earth.

More recently, there appeared in the *National Geographic Magazine* one of the most remarkable photographs ever taken. This was also the work of Captain Stevens, and showed the whole of greater New York and much surrounding country in surprising clarity of detail with complete elimination of the haze. It was made not using invisible infra-red rays, but with the deep red rays near the ex-

treme of the visible spectrum. There is much aerial survey work done, both in time of peace as well as during war. It enables maps to be constructed accurately at a cost very much less than when the normal methods of surveying from land are employed. However, when the photographs are taken from such a height that there is no blurring due to motion of the airplane and that sufficient territory appears in the picture, atmospheric haze invariably spoils the definition of detail in the photograph. Such pictures are, therefore, always made with the more penetrating longer red light of the visible spectrum or, more recently, with the region of the infra-red near to the end of the visible red.

It has been suggested that the use of infra-red photography might be of value in enabling sailors to navigate ships with safety in dense fogs at sea, and infra-red cameras have been installed on a number of ships. It is known, however, from theoretical grounds, and practical results have confirmed it, that no increased penetration could be obtained in the case of a fog which was a danger to navigation. But, even if such photographs can not be used for navigation in all kinds of fog, a fleet of airplanes equipped with infra-red cameras for penetrating the lighter haze which cuts down visibility could be of real value as a scouting arm attached to a battle fleet in time of war.

In the later years of the last century, Captain Abney, a foremost British photographic investigator, produced some plates which were sensitive to the infra-red. His results are of historical interest only, because his plates are very difficult to make and use. He did, however, succeed in photographing the spectrum of the sun to a wave-length beyond 10,000 Å., an achievement which it has only been possible to repeat in recent years. The present limit is 13,536 Å., recorded of late by Babcock of Mount Wilson Observatory using some remarkable plates prepared by the Kodak Research Laboratories. As a result of his experiences with the infra-red, however, Abney suggested that it might be possible to photograph a kettle of boiling water in the dark, using the heat rays given off from it. So far this has not been done, but using modern plates, it has been a relatively simple matter to photograph bodies at a somewhat higher temperature than boiling water, using the heat rays which are quite invisible to the eye. For instance, an electric flatiron can be photographed in total darkness, making use of the invisible waves radiated by it.

Still more interesting is the fact that photographs have been made of a plaster bust in the dark, using two flatirons instead of the lamps which would be used in taking an ordinary photograph. Of course, it would be very unpleasant for a human subject to be subjected to the heat from two irons while his photograph was being made. (We can discredit the schoolboy's story that Henry VIII used a flatiron when he "pressed his suit on Anne Boleyn.") It was for this reason that the plaster cast was used. The ordinary electric lamp, however, gives off a relatively large proportion of its rays in the invisible infra-red. So, if it were possible to screen lamps with filters which do not let through any visible light, and use plates sensitive to the infra-red, it should be possible to photograph people in the dark without subjecting them to much physical discomfort. This has been done on several occasions with very short exposures; even motion pictures have been made in complete darkness.

Portraits by infra-red rays are not characterized by any degree of beauty. In them the flesh appears chalky, the red lips come out light, the eyes appear as black circles, and all lines in the face are enormously exaggerated. Effects such as this are due to the peculiar way in which materials reflect and transmit the infra-red. It is not possible to tell from the appearance of an object by visible

light how it will reflect the invisible radiations. By infra-red, for instance, there is a practically complete elimination of the stripes and the background of the stars of the United States flag. A series of pieces of black dyed cloth can be selected which look equally black to the eye, but in the infra-red photograph they appear as a scale of grays ranging from white to black. It is possible to photograph a Negro in a black suit and in the print find he looks like a man with fair skin in a Palm Beach suit! In an infra-red picture of a landscape the leaves of the trees look very light, giving the trees the appearance of being covered with snow. This effect is obtained because the chlorophyll in the leaves, which gives them their dark green color because it absorbs blue and particularly red light, reflects the infra-red very freely.

Now this characteristic which many materials possess, of reflecting and transmitting the infra-red much more freely than they do visible light, has given some results of very considerable interest. Suppose, for instance, a photograph is made of a man's chest by infra-red. The picture will differ very markedly from a normal photograph and from what is seen by the eye. The veins will be clearly visible in it. These veins are actually invisible to the eye because they are buried beneath the layer of skin. A result such as this might be expected, if it were remembered that infra-red rays are used in therapy for warming up the muscles below the skin. The fact that they can be used for this purpose shows that they can penetrate skin and flesh. It will immediately be said, "Well, then, why can not we use infra-red pictures as a means of medical diagnosis, to show incipient afflictions having their origins below the skin?" This has already been done, and is being extensively studied at the moment, and the results are of great interest. Varicose veins and congestion of the capillaries can be seen, and the study of skin lesions is being actively investigated. It appears that here we have a tool which may one day prove of considerable value to the doctor. Would it not be of importance if we could show the presence of diseases before the skin took on its characteristic appearance? Certain diseases of plants have already been diagnosed in their early stages in this way by infra-red photography of the leaves.

Among the old works in the Huntington Library at San Marino, California, is a copy of De Bry's "Voyages." Some passages in this work were considered objectionable by the censors of the Spanish Inquisition, who deleted them in the year 1632 with a layer of black ink—so thick that it can in places be felt as a ridge by the finger—and completely obliterating the offending passages. Dr. L. Bendikson, of the Huntington Library, heard of the success with which the astronomers at Mount Wilson Observatory had been using infra-red plates, and borrowed a few to see if they would help him in deciphering the old books. He had already tried ultra-violet without success. To his delight he found that infra-red could penetrate the censorial ink, showing up the underlying printed matter as if the inquisitor had never existed. It was fortunate that the censor knew nothing of the properties of his inks in the infra-red, or he might have chosen one having the same characteristics as the ink used for printing the book, and our librarian would have been foiled.

Dr. Bendikson, prompted by his success in this instance, then turned his attention to some of the documents which had been badly charred by fire in the disaster which occurred in the New York State Capitol at Albany more than twenty years ago, causing serious losses to the State Library. Here again, he succeeded in deciphering passages which had been rendered quite illegible by the fire.

There is another way of deciphering

charred documents, which was worked out in the Bureau of Standards some years ago. In this case, the charred page is merely put in contact with a photographic plate and left in the dark for several weeks. On developing the plate a negative image of the original writing is found from which prints can be made and the writing read with surprising clarity. This method has been used with success by a number of examiners of questioned documents, mainly for deciphering important financial documents such as ledgers, bonds and checks which have been rendered illegible by charring.

During the course of the excavations which have been going on in Herculaneum in Italy, many old rolls of Roman papyri have been discovered, which were completely charred during the eruption of Mount Vesuvius which overwhelmed the city. These charred rolls are so fragile that it requires exceeding care to open them out flat so that they can be studied. But when this is done it is found that the old writing is practically invisible. By very skilful arrangement of lighting and astute methods of increasing contrast photographically, however, Signor Ferdinando Lembo of Naples has succeeded in photographing them in such a way that the records have been able to be read with ease by the historian.

So far we have considered mainly those things which are invisible because the radiations which announce their presence are outside the range to which the eye can respond. There are other things, however, which emit light of such a low intensity that the eye can not see them, and there are events which take place so rapidly that our senses are unable to arrest any impression of them. These rightly fall under the heading of the invisible.

The photographic plate possesses an attribute additional to those already mentioned, which gives it another advantage over the eye. It can go on building up an impression as long as it is exposed, so that eventually those things which are so weak as to give no record when exposed for a short time, can be made to build up an image of any desired intensity. The eye can not do this. If a source of light is so weak as to be below the threshold of sensitivity of the eye, it remains invisible however long we look at it.

Without photography, our knowledge of the universe would be but a very small fraction of what it actually is, even if we consider merely the numbers of stars and ignore what we have learned of their constitution; for many of them are so weak as to be quite invisible, even in the highest power telescope. Suppose we were photographing a portion of the constellation of Orion, and that in making it, two exposures were given, one one hundred times as much as the other. If the shorter exposure showed a few of the most prominent stars, the longer one would show a very large number of stars large and small. Perhaps at the bottom of the photograph would be the great first magnitude blue star, Rigal; above it the Sword Belt, and in the curve of the sword an object which does not form a sharp image on the photographic plate. It is the great nebula of Orion, one of the most wonderful objects in the sky. Photographed in the highest power of the telescope, in the middle of the nebula is a great dim cloud of light, in the words of Sir James Jeans, "looking like drifting masses of smoke such as one sees when a house or a haystack is on fire. And, indeed, they are, so to speak, only the smoke of our own star-city, lighted up by the lights of our own star-city; they are the wisps and clouds of dust and luminous gas stretching from star to star within the confines of the Milky Way, and forming light and dark patches against the sky, much as the smoke and flame of an ordinary fire form light and dark patches against the sky." In the way that the photographer has been able to penetrate the haze on earth, revealing

the detail of his distant landscape, so the astronomer has been able to penetrate the haze of his nebulae, revealing through them images of faint stars invisible in a usual photograph, masked by the luminous gases.

At night time, in the headlights of our cars, we see repeated flashes, bright points of light, appearing and disappearing, but moving rapidly with respect to us, and giving no impression of well-defined form. The state of our radiator and windshield after the journey shows that we were observing the flight of insects. If we were able to arrest them at any one part of their path, and fix a stationary image of them on the eye for a short time, we might be able to recognize their form. If we can not recognize a flying insect, still less can we identify more rapidly moving objects, such as a golf ball or the bullet fired from a revolver. But, here again, photography comes to our aid, and provides us with a means of arresting their rapid flight.

A golf ball, struck by an average player in making a drive, leaves the club at a speed of about 180 feet a second. Now, the shortest exposure usually available on the best of photographic cameras, such as those used by press photographers, is one thousandth of a second. In this short interval of time the golf ball moves two inches, and in the photograph it would appear as a white blur two inches long. We can tolerate a movement of the ball of only about 1/50th of an inch while the exposure is being made. With this a reasonably sharp picture can be obtained. The ball, however, moves 1/50th of an inch in 1/200,000 part of a second, an exceedingly short time, quite unattainable with a mechanical shutter on a camera. Even if it were attainable we should be faced with the problem of providing enough light to give a good photograph in such a short time. Fortunately, there are means available which can produce very bright flashes of light of exceedingly short duration. One of these is the electric spark; the other is a discharge through a mercury arc lamp. Using this second method Edgerton, of the Massachusetts Institute of Technology, has made a series of very interesting studies of high-speed phenomena. One of his photographs shows a golf club at the moment of its impact with the ball. The ball, before it has moved from the tee, is clearly very considerably compressed, flattened at the side in contact with the club. The club and ball travel together for a distance not exceeding one half of an inch, the ball then races ahead of the club, flattening next in a direction at right angles to its former direction of compression, then oscillating somewhat, and all the time revolving backwards at a rate of 5,000 revolutions a minute. Without photographs such as these, taken in 1/200,000 of a second, we could learn little of the mechanics of the flight of the ball. (At the same time such knowledge is not calculated to improve the standard of the player.)

By using the newly developed technique of high-speed photography, it is possible to study the movement of flame in mixtures of explosive gases. Such studies are of immense importance in those fields where it is desired to eliminate explosions, as in the mining industry, or where it is deliberately desired to use them, as in the design of internal combustion engines. One of the earliest scientific applications of photography was in the photography of flame, some 50 years ago, shortly after the photographic material of the general type we now use was introduced. With the development of high sensitivity and other properties in photographic plates and films, and new lenses having high apertures, enormous progress has been made in the study of explosions. There are two ways of studying flames photographically. In one a series of snapshots of the flame is made in succession at very short intervals on a plate or film, showing consecu-

tive stages in the propagation. In the other method, a plate or film is made to move rapidly in a direction at right angles to the path of the explosion, an image of the flame being focussed on the plate or film by a lens. A trace is obtained, from the slope of which the speed of the flame can be calculated.

In an explosion in a mixture of gases, the flame can travel at velocities varying from 0.3 to 3,500 meters per second, or, say, one half to seven thousand miles an hour. But whatever the velocity, the rate and characteristics of the explosion can now be satisfactorily studied. In the hands of Fraser, of the University of London, and Ellis, of the University of Cambridge, extremely valuable data have been collected in this way on the course of explosions in mixtures of gases, and particularly, the behavior before and after detonation.

Perhaps the most fascinating of all examples of high-speed photography is that of the photography of bullets propelled from firearms. The earliest work of this kind was carried out by Professor C. V. Boys in England, but the best photographs are those made a few years ago by the late Philip Quayle at the Bureau of Standards. In the system employed an intense electric spark of very short duration is used to take the picture, although the method of taking it is not as simple as might appear. The bullet travels at a rate of some half a mile a second, and the camera has to get a glimpse of it before it passes from its field of view; elaborate electrical apparatus is necessary to ensure this, and to provide the two millionth of a second flash necessary to give a glimpse of the bullet's flight and record its image on the plate.

A series of photographs of a bullet being fired from the muzzle of a revolver is very instructive. When the bullet is just clear of the muzzle, the gases which have leaked past it, and the powder particles which were left in the barrel after the previous discharge, are seen ahead of it. The sound wave generated by the release of the gas, and which is audible as the familiar crack, is just being formed. When the bullet is $1\frac{1}{4}$ inches out of the muzzle the sound wave has grown to 3 inches. The bullet is no longer being accelerated by the expanding gases. Both bullet and the sound wave move on, until soon the bullet passes clearly through the wave and flies ahead of it. The projectile, now in free air away from the muzzle, generates sound waves itself, due to its head, its base and the rifling marks; they are like the waves on the sea, the wake of a speed boat or a fast-moving liner, and cause the whine of the bullet in flight. Information obtained in this way has proved of great help in studying the phenomena attending the discharge of firearms. It is but one more illustration of the application of photography to aiding the understanding of technical problems, and in enabling us to "see the invisible."

And so we see how photography enlarges the scope of the eye, enabling us to study events which take place too rapidly to be followed in detail, or which are not bright enough to be seen; stretching our vision beyond the limits of our ken to the realm of radiations to which our senses will not of themselves respond. Before the eye of the camera the universe unfolds, and the secrets of matter are slowly giving way. This is the age of progress and in it the century-old art is playing a prominent part. We are in an era of great scientific discovery, which has come about largely because of the insatiable curiosity of the scientist. Must we not change our adage, and say of him: "What the eye can't see, the heart *does* long for?"

NUMBER AND CLEAR THINKING

AN ASPECT OF HUMAN CULTURE

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The earliest impacts of number on human culture, that is, on the intellectual and esthetic content of civilization, are lost from our view in a prehistoric past so distant as to deny all hope of recovering precise facts concerning them.

It is doubtless true that a certain number-sense was developed in human history long before numbers made their explicit appearance. A child may well observe that one object from a collection of four similar objects was removed while he was not looking, though he is still unable to form such a concept as is involved in the words three and four. It appears, in fact, that some animals have developed a certain number-sense. A bird may continue with a nest when one of four eggs is removed but desert it if two are taken.

He who first observed the common element in *two* days and *two* stones, took a great step forward in the development of human culture, going well beyond what the preman saw who first observed that two stones might kill a snake while one would not. To recognize that property of two collections from which it arises that they have the same number of elements requires no little power of perceiving abstractions. But these preliminary stages in the development of the number concept are lost in the mists of prehistory.

Primitive cultures still exist in which there is only a very partial development of the number concept. It is tempting to suppose that acquaintance with these may throw some important light on the history which has culminated in our own acknowledge of numbers. But to make such a supposition is merely to speculate: the facts are unknown. And there is indeed an element which might well cause us to hesitate. It appears probable that the total history of primitive cultures is chronologically as long as our own, even though it seems to us reasonable to suppose that it is not so rich in details. It would follow, then, that the development of those cultures which are still primitive has proceeded at a different rate from ours; and this fact is undoubtedly significant. It is therefore unsafe to read our knowledge of present-day primitive cultures into our own history.

It is clear that considerable progress with the understanding of number must have been made long before the invention of any written language suitable for recording the early steps. The first glimpses into the literary records of human culture reveal number as already on the scene; and it is playing a rôle which it could have assumed only after a long preceding historical development. The positive knowledge which we can create through the investigation of ancient remains has already lost much of its precision when we press back as far as 4000 B.C.; and literary documents of any clear adequacy are first to be found only at later dates. But a long and flourishing mathematical and architectural development must already have taken place before the ancient Egyptians could have brought into existence the magnificent structures of the third millennium before Christ. And far beyond that must our mental vision pierce into the darkness to see the beginnings of

that development which enabled the ancient Babylonians to deal effectively with square numbers and with sexagesimal fractions.

Even when records begin to appear there is some evidence that the most active mental experiences with numbers were not recorded. In the computations of the ancients, "head reckoning," or mental arithmetic, was apparently more widely employed than written work. It is known that such mental reckoning was required of students in some of the ancient schools. An extant Egyptian document from about 1300 B.C. contains an admonition to pupils running about as follows: "When you are computing silently, let no spoken word be heard." (But the ancient Egyptians are not known to have raised the behavioristic question whether the mind or the larynx was computing.) It is evident that the wide-spread use of this head reckoning would tend to decrease such documentary evidence for the number processes employed as might persist to our own day.

We must pass over the remaining aspects of the beginnings of things, not even taking time for such an interesting and remarkable document as the Ahmes papyrus from Egypt with the intriguing title, "Directions for Obtaining the Knowledge of all Dark Things"; we remark merely that this ancient treatise, devoted largely to properties of numbers, indicates by its title that there is nothing novel in the subject "Number and Clear Thinking"—the theme is hoary with millennial wisdom.

It is with Pythagoras (sixth century B.C.) and the Pythagoreans that the concept of number first comes into explicit precise verifiable relations with the problem of clear thinking. The historically important part of the work of Pythagoras, though preceded by a period rich in experience, begins with his migration to Crotona in Italy about the year 529 B.C. Here he became the center of a great organization having in some respects the character of a religious brotherhood or an association for the moral reformation of society. The intellectual advances made by this school arose in the atmosphere of moral earnestness and social reform. But the scientific doctrines themselves appear to have had no intimate connection with the religious mysticism of the society or the rules of conduct of the brotherhood.

The central aspect of Pythagorean philosophy lies in its recognition of the numerical and mathematical relations of things. In the earlier times the dim realization of these abstract considerations led to the assertion of the essential existence of numbers as the causes of phenomena or of the still more specific proposition that number is the essence of everything. Aristotle tells us: "The Pythagoreans seem to have looked upon number as the principle and, so to speak, the matter of which existences consist." Again he says: "They supposed the elements of numbers to be the elements of existence, and pronounced the whole heaven to be harmony and number." Philolaus, a later Pythagorean, says: "Number is great and perfect and omnipotent, and the principle and guide of divine and human life." Fantastical this may be (and perhaps removed from clear thinking) but nevertheless it is prompted by the underlying truth that "it is number or definite mathematical relation that separates one thing from another and so in a sense makes them things." Thus number was recognized by the Pythagoreans as the principle of order, the principle by which the world, instead of being a chaos, becomes a cosmos. The chief grounds for their theory they found in the regular movements of the heavenly bodies and in the harmony of musical sounds dependent upon the arithmetical ratios of small integers.

The theories of the Pythagoreans have

their reverberations even up to modern times. Let us illustrate with quotations from English literature:

Billingsley (1570): "Nomber compasseth all thinges, and is . . . the being and very essence of all thinges."

Argyll (1857): "These laws of number and proportion pervade all Nature."

Steele, *Spectator,* No. 174: "Numbers are so much the measure of everything that is valuable that it is not possible to demonstrate the success of any action or the prudence of any undertaking without them."

Thus the doctrine persists in literature, even if it has become somewhat attenuated. Moreover, it also has a certain precarious existence in everyday living and conversation. The possession of precise information about a person's ability, character, intentions, psychological disposition and even moral integrity, serving to identify him (in essence and substance) as belonging to a certain type, may be indicated by a succinct and expressive colloquialism, redolent of Pythagoras, namely, "I've got your number."

When we are told how Pythagoras insisted that mathematical objects, such as numbers and shapes, are the ultimate stuff out of which the real entities of experience are constructed, we may at first feel that the idea is crude or indeed silly. But when we recognize that he is reaching toward the proposition that to know something perfectly general about the elements in any situation is to know many other equally general concepts which are exemplified in that situation, and when we realize that the history of thought has proved the presence of this general truth in these speculations, we begin to see in Pythagoras the first man to get any clear grasp of a general principle which has exerted a profound influence upon clear thinking for more than two millennia. He was insisting upon the importance of the utmost generality in reasoning and he saw the essential character of number as a necessary element in the construction of intellectual tools for understanding nature.

The intrinsic importance of Pythagoras necessarily lies primarily in his own thought; but the influence of any thinker owes something to chance. In order to be influential historically one's work must be taken up effectively by later thinkers. Pythagoras was fortunate in that his speculations germinated in the mind of no less a thinker than Plato. The Platonic world of ideas was developed from the Pythagorean doctrine that number lies at the base of all things in the real world. By arranging numbers in patterns of dots, according to the Greek fashion, one begins to associate shapes with numbers; and thus Pythagoras was led to include form in connection with his doctrine of number as underlying all things. "So today," says Whitehead, "when Einstein and his followers proclaim that physical facts, such as gravitation, are to be construed as exhibitions of local peculiarities of spatio-temporal properties, they are following the pure Pythagorean tradition."

Between the epoch from Pythagoras to Plato and that of modern scientific discovery stretches a long period of development in which the human mind, building in each generation on the intellectual heritage from the past, has moved from one stage of conquest to another, very slowly at times, but with astonishing swiftness in recent generations. Great scientists, great philosophers, great mathematicians have sought to realize in some measure the abstract generality and inclusiveness foreshadowed in the speculations of Pythagoras concerning the nature of number and the nature of things. If Pythagoras could have foreseen the issue he would have had one additional justification for the excitement which prevailed in his brotherhood.

There is another aspect of Pytha-

gorean thinking about number which I must bring to your attention, owing to the important bearing which it has (in another direction) upon the problem of exact thought. The discovery in question has had a profound influence on the development of the modern theory of irrational numbers. To prepare the way for presenting this discovery let us first say a few words about the early Greek conception of number and of the place of number in a theory of measurement.

The early Greeks did not think of one as a number: to them it was the unit out of which number is generated, while a number was always considered as a collection of units. Thus for them numbers were the positive integers 2, 3, 4, . . . Some of the later Greeks would sometimes speak of one as a number. What we would denote by a fractional number, such as $\frac{2}{3}$, the Greeks would subsume under the notion of ratio. The number speculations of Pythagoras would therefore be confined to the positive integers 2, 3, 4, . . . , with the unit 1 playing a special rôle of its own.

Measurement, in its primary aspect, consists essentially in the comparison of two given lengths. The Pythagoreans inclined, almost instinctively, it would seem, to express this comparison by aid of a common unit of length which would be contained in each of the given lengths an exact integral number of times. To get the effect of their point of view we might think of two lengths, one of 3 and $\frac{1}{3}$ inches and one of 2 and $\frac{1}{12}$ inches, for instance, as measured by means of a unit $\frac{1}{12}$ of an inch in length, this unit being contained in the two indicated lengths 40 times and 25 times, respectively. If we should use a unit 5/12 of an inch in length, and hence five times as long as the preceding unit, then it would be contained eight times and five times respectively in the two given lengths.

Now Pythagoras conceived the ideal lines present in geometry as natural elements truly existent to the mind. His number speculations regarding the nature of things would therefore cause him to seek a common unit in terms of which to measure by means of numbers (positive integers) any two lengths which might be presented to thought. And any failure in such an attempt would be a serious blow to his number speculations. Just such a failure confronted him. He observed the existence of two lines not having a common unit of measurement: and this fact produced much consternation.

The discovery was made in this wise. Pythagoras, so it is said, had proved the general theorem that the square on the hypotenuse of a right triangle is equal to the sum of the squares on the two sides. Now consider a right triangle with two equal sides, and seek a common unit for measuring a side and the hypotenuse. Suppose that such a unit exists and is contained m times in the hypotenuse and n times in a side, m and n being positive integers. Then the square of m is twice the square of n. Hence the measure m of the hypotenuse is necessarily an even number. Now drop a perpendicular from the vertex of the right angle to the hypotenuse. This divides the original right triangle into two equal right triangles, each of which has a hypotenuse of length n and sides of (integral) length $\frac{1}{2}$ m. Since n measures the hypotenuse of one of the new triangles, it follows from the foregoing argument that n must itself be even. Since m and n are both even we may double the original unit of length and still measure the side and hypotenuse of the original triangle in positive integers. But from the former argument these latter integers are both even. Hence the unit of length may again be doubled without interfering with the required type of measurement: and this process of doubling the unit of length

may be repeated indefinitely without hindering the measurements. Since this conclusion is manifestly absurd it follows that the original hypothesis of a common measure for the side and the hypotenuse of an isosceles right triangle is incorrect. Therefore no such common measure exists.

This difficulty in the connection between integral numbers and things was clearly perceived by the Pythagoreans. Whether the foregoing proof of the existence of this difficulty is that employed by them I do not know, but it is certain that it runs entirely in terms of ideas to which they gave much attention. The result confronted them with a great challenge in their attempt to think clearly about the nature of measurement; and that challenge has been highly fruitful of ideas and theories both in mathematics and in all those parts of science which depend upon theoretical precision of measurement.

Here we find the beginning of that process by which mathematical analysis has, in modern times, been reduced to an arithmetical basis. Prior to this reduction the conception of the continuum of points on a line and of their mutual distances as the basis of measurement was intuitional in character. The same intuitive idea also underlay the concept of continuous motion. In order that a particle might move in a straight line from a point A to a point B it was said to be necessary that it should pass through every intermediate position in the line. But there was a failure to make a careful analysis of what is meant by *every* intermediate position. As long as one relies upon a vague intuition of this *everyness* there is lack of clarity in thought; essential difficulties are involved which can be removed (if at all) only by a thorough analysis of the whole situation.

You will not expect me to follow through in detail the arduous steps of progress from the Pythagorean discovery of the existence of incommensurable magnitudes, and hence of what we would now call irrational numbers, to the modern analysis of the continuum of points on a line. It took the human mind well over two thousand years to pass from the first step in this direction to the attainment of a fairly satisfactory foundation in relatively recent times. But this development has proved itself essential in making secure the foundations of mathematical analysis and in providing an adequate theory for scientific measurement.

Kepler was convinced that God created the world according to number, and this conviction inspired his arduous labors in seeking the real cause of planetary motions. He was not tediously searching for empirical rules: he looked for ultimate causes; he sought in number the secret of the Creator's mind. It is an irony of history that Newton replaced his mystical doctrine of numbers with a mechanical explanation in terms of the laws of force and motion.

The law of gravitation, as developed by Newton, is expressed by means of a very simple relation among numbers. Into this relation is incorporated a wide range of experience and observation; and from it prediction of further scientific results can be deduced. There is probably no other law or principle in science whose history bears so many indications of distinction. The work of Newton is marked by a clarity and penetration of thought and a lucidity of reasoning not previously experienced by man in thinking about the things around him. The numerical precision of results is so great that even very small discrepancies between theory and fact must be revealed if they exist and measurement becomes sufficiently refined to detect them. Thus from precision of thinking and clarity of result it became possible to compare Newton with Einstein

and finally to accept the latter as against the former. Without the clearness and exactness of result contributed to thinking by number such choice would be impossible. And after relativity has thrown so much of human thinking into flux and the stress of intellectual clash has finally subsided, we find emerging from the relativistic battleground at least one absolute of thought: there is nothing in the theory of relativity to alter the count of a finite collection of objects. The absoluteness of the positive integer is vindicated even in the theory of relativity.

Though irrational numbers are necessary for an adequate theory of measurement there are still wide domains of science in which the positive integer reigns supreme. It lies at the root of the atomic theory. It has attained a new dignity in modern quantum phenomena. If it should turn out that space and time, as well as matter and energy, are atomic in character, it might very well happen that a new foundation for science would be laid entirely in the theory of positive integers. This would certainly serve to redirect the labors of mathematicians in the theory of numbers; and in science it might carry us far back toward the original views of Pythagoras.

One of the most marked relations of number to clear thinking in biology is that involved in the Mendelian theory of heredity: and here it is essentially the positive integer which plays the leading rôle. This theory affords good evidence of the importance of number in stimulating clarity of thought and in leading the way to developments having wide contacts and yielding far-reaching results.

We may allow the statistical element in the results of Mendel to remind us of the very considerable range of phenomena which are accessible to clear and precise thought only through the use of statistical methods—and these depend intimately and essentially upon number. But we can not feel highly elated over our success when we remember that even the wide use of statistical methods has left us unable to attain clarity of thought about the weather, even though there is nothing else with which we have lived longer or more variously.

We have always realized our failure to understand the weather intimately. But we have sometimes carried out processes of thought, where it seemed for a time that clarity had been attained by aid of numerical exactness, and have afterwards had the experience of finding that what was accepted as valid and important has not continued to carry the confidence that it had once inspired. Not even the presence of number is sufficient to always save us from stupidities. In the older psycho-physics, for instance, there seems to have been a misleading precision in some of the exact formulas put down as the results of experiments.

It must also be remembered that there are important chapters of science which do not come readily under the domain of number. Witness much of biology and in particular the theories of phylogenetic development. As another example: It is difficult to see how the Gestalt psychology, with its emphasis on form and configuration, can be reduced fundamentally to terms esssentially involving only number. The task is even more forbidding in the case of psychoanalysis.

But enough has been given to show that precision of thinking may inhere in living thought and be supported by number; it is not solely the dead bones of truth that are subject to numerical precision. The changing contour of an organism of knowledge which pulses with life may be understood in the relations of its parts with a precision comparable to that which reigns among numbers; and exact numerical conditions

are often the means by which we understand the active life of living thought.

If I may be allowed to vary somewhat an English translation of a stanza of Schiller's, I may speak thus:

> No Augustan epoch flowered,
> No Maecenas favors showered
> Ever Number Science on;
>
> She was not by glory nourished
> And her blossom never flourished
> In the rays of Royal sun.

On the contrary the development of the science has grown out of the delight experienced by certain intelligent spirits in unfolding the relevant concepts and drawing appropriate consequences. And such delight is all the justification needed for any conquest over ignorance—the sort of conquest that never leaves any lingering regret—or any Polish Corridor. But the human mind is so constituted that when one thinks for sheer joy he is very likely to run into matters having philosophical implications. This and the fact that abstract number theory arose in a school of philosophy might lead us to expect that number has important contacts with general speculation. We shall now see that this is so and moreover that number has so tamed the beast of speculation as to bring some of his wild jungles under the plow of intellectual cultivation.

But before we take up that matter let us digress, by way of recreation, to hear a warning to any mathematician (if one exists) who is inclined to trust too much to his power and facility in handling numbers. This warning will be presented in the quaintly harmonious phrasing of an old English poem having peculiar and haunting rhythms. The verses run as follows:

> He that seeketh to *compute* his way to the wonders of mathematics
> And delighteth not in ideas
> Shall be grievously tormented:
> In anguish he shall die in the wild jungles of formulas,
> His heart shall be pierced by the poisonous symbols:
> But he that meditateth frequently in silence
> And seeth the truth oft without symbols
> And delighteth much in ideas comprehended
> Shall get marvelous strength from the dangerous symbols
> And tame the jungles of wild formulas;
> He shall roam at his will in their borders,
> Constraining their giants to his bidding,
> Unfolding the truth for the ages;
> And in joy he shall bring the gift of his thinking
> And bestow upon man a perpetual blessing,
> And for a while he shall be gratefully remembered:
> But he that seeketh to compute his way to the goods of the science
> And delighteth not in ideas
> Shall be grievously tormented:
> In anguish he shall die in the jungles of wild formulas,
> And oblivion shall cover him over with kindly forgetfulness.

If this recreation is insufficient and you do not yet feel like submitting your mind to the arduous task (now before us) of engaging in abstract considerations about infinity, I would suggest to you a little exercise in applied philosophy: while I talk about infinity, and some other things of like magnitude, you might amuse yourself by considering whether an after-dinner lecture is *really* infinite in length or only *seems* so.

As I proceed, you must understand that I mean to talk about what is really infinite and that I am not using the word loosely and irresponsibly, as Southey did when he said (in 1796) that "the number of fools is infinite."

The subject belongs to the domain of number as Locke had already divined in 1697 when he said: "Our idea of infinity . . . seems to be nothing but the infinity of number."

The unlimited straight line can not be measured off by the repeated application of any unit of length, however great; beyond any point on it which we can imagine, we can think of another

still further away, and of another beyond this; and so on. We may therefore say that the line is infinite in length. Any line segment, however short, may be separated into equal parts; and each of these parts may be separated into halves; and these latter may again be so divided; and so on without end. A line segment is infinitely divisible.

However far back into the past we extend our thought, we can conceive a time still earlier, and then another preceding this, and then a still earlier one, and so on *ad infinitum.* Beyond any future time conceived we can think of another still more remote. Time seems to be infinite in both directions.

There is a shorter distance than any we have measured and a longer than any we have conceived. No clock can fix an interval of time so short that we can not conceive a shorter. No geologist or astronomer has used so long a period that we can not think of a longer.

All these things bring the infinite to our thought; but the infinite as it emerges here appears always in a negative aspect. It is that which is not attained to by the finite. Such an infinite is that vague incoherent thing which remains over and beyond the reach of the finite. These conceptions present the infinite to us only as that which is not something else, that which is not the finite. But we can hardly come to understand the infinite merely by saying what it is not. If we are to be clear in our thinking about it we must say what it is.

The notion infinity appears in mathematics in two essentially different ways.

If a given magnitude x is variable and is subject to a law of variation such that x becomes and remains larger than any whatever preassigned magnitude that may be named, then x is said to become infinite. If a positive variable becomes and remains less than any assigned magnitude, however small, then we say that x is infinitesimal and approaches zero. These concepts of the infinite and the infinitesimal are closely akin to the infinitudes of measurement and of subdivision about which we have spoken already. While the concept of infinity is usually invoked here, as we have indicated, it is nevertheless not strictly applicable. If one carefully inspects the definitions given, it will be seen that they run entirely in terms of the finite and that no transcendental numerical idea is involved in the statements of them. Here we have not the genuine concept of the infinite but rather of certain types of variation.

The most remarkable, and at the same time the most characteristic, mathematical doctrine of the infinite is that which belongs to the theory of the so-called infinite aggregates or infinite classes. It is defined by means of numbers in accordance with the prophetic dictum of Locke already quoted. While it may be true, as Samuel Johnson said to Boswell on March 16, 1776, that all minds are equally capable of attaining the science of numbers, it is also true, as Johnson further said on the same occasion, that the type of one's education makes a great difference in the facility one has in penetrating to an understanding of number-theoretic considerations. I shall therefore have to ask your patient attention to some preparatory details if you are to understand the definition of infinite classes now about to be presented.

Suppose that you are in a Christian country and are attending a party where it is known (if I may speak formally, as the mathematicians do) that for every woman present there is a man present who is her husband and that for every man present there is a woman present who is his wife. Then you do not have to count those in attendance in order to know that the number of men present is the same as the number of women. Since by hypothesis this is taking place in a Christian country, the marital relation

establishes a one-to-one correspondence (unfortunately, we can only *hope* that it is a permanent one) between the men on the one hand and the women on the other of such sort as to imply equality in the numbers of the two sexes present. Moreover, you would also readily know something more about this group of men and women, as we shall now see.

Suppose for the moment that the men are all placed in line and that each woman takes a position just in front of her husband—it seems to be the present-day expectation for her to be thus a little ahead of him. This will exhibit to the eye the one-to-one correspondence already mentioned. Now suppose further that the men remain in position while the women assemble in a group and then separate again, each taking her position in front of a man but not necessarily in front of her husband, getting ready, let us say, to go out to dinner. This arrangement will set up a new one-to-one correspondence between the men and the women—let us hope that it will be a temporary one. It will be found, as you will readily agree, that the one-to-one correspondence is complete in the sense that there is no man not accompanied by a woman and no woman not accompanied by a man and that to each person of either sex there is assigned just one person of the opposite sex. A trivial observation, you may at first be inclined to say. Not at all. It is a fundamental fact: indeed it is perhaps the most important fact there is about two equal finite classes when considered from the point of view of finiteness and equality of numbers in the two classes.

This observation may indeed be used to define a finite class. A class A is said to be finite if there exists a class B whose elements can be put into one-to-one correspondence with the elements of A and if furthermore it is true that however the elements of A (without omission) are put into one-to-one correspondence with elements of B the process completely exhausts the elements of B.

If this definition is not clear, it may be well to go over it again, thinking of the class A as the men in our fictitious party and the class B as the women.

A corresponding definition of infinite classes may be given. A class C is said to be infinite if there exists a class D whose elements can be put into one-to-one correspondence with the elements of C, while at the same time it is true that the elements of C (without omission) may be put into one-to-one correspondence with a part of the elements of D, some of the elements of D (or at least one of them) being omitted in this correspondence.

If you have never before thought of these matters such a thing may well seem to you to be impossible. But, that there actually do exist infinite classes, in the sense of this definition, you may readily be convinced in the following way. Let us think of the totality of all positive integers 1, 2, 3, . . . , attaching to each of them the color blue (or writing it with a blue pencil) for the sake of identifying it as belonging to this particular class. We shall now prove that these blue integers form an infinite class, in the sense of the foregoing definition. To do this let us exhibit the class of red integers 1, 2, 3, . . . (written, let us say, with a red pencil). A one-to-one correspondence between these two classes may be set up by making the following correspondences: blue 1 to red 1, blue 2 to red 2, blue 3 to red 3, and so on. In this correspondence each class is uniquely exhausted. But note also that we can make the blue integers correspond completely, in a one-to-one way, to a part of the red integers, as follows: to blue 1 assign red 2; to blue 2 assign red 4; to blue 3 assign red 6; and so on; to each blue number assign the red number which is just twice as large. You will agree with me, I believe, that the blue integers are uniquely exhausted and are

in one-to-one correspondence with only a part of the red integers, indeed with just every other one of them and hence with just half of them.

The blue integers therefore form a class which is infinite in the sense of the foregoing definition. It is easy to prove similarly that the red integers also form an infinite class.

You will observe that the definition of infinite class which we are now employing is not a negative one. In this definition we do not define an infinite class by saying what it is not, but by saying what it is. This conception of infinity, when it first appeared, marked a great step forward in clear thinking. While it may be true that the inventor of this definition, as well as the mathematicians who have followed him, have been too profoundly convinced of its importance to present it in the colorful holiday garb which I have introduced here, it is nevertheless true that the playfulness has in no way obscured the fundamental idea underlying the definition. It is hoped that the Christian party and the colored numbers will afford an aid in remembering one of the most fundamental facts about infinite classes; indeed, just that one which separates them most sharply and most characteristically from finite classes.

In the case of the two infinite classes which we have had before us, namely, the blue integers and the red integers, it will be remembered that it was found possible to put the classes into one-to-one correspondence. The question naturally arises whether two infinite classes can always be put into one-to-one correspondence. The answer is that this can not always be done, that it is possible to exhibit pairs of infinite classes such that elements of the two classes in a pair can not be put into one-to-one correspondence. This justifies us in saying that infinite classes exist which are not of the same magnitude. If two finite classes can be put into one-to-one correspondence then the number of elements in one of the classes is equal to the number of elements in the other. We may say that the two classes have the same magnitude as to number. If two infinite classes can be put into one-to-one correspondence, we may likewise say that they have the same magnitude as to number. If two infinite classes can not be put into one-to-one correspondence, then we may (and we do) say that they have not the same magnitude as to number. In fact, it is customary to refine this conception of difference in magnitude of two infinite classes in such a way as to justify us in saying, under certain conditions which have to be specified with care, that one of two infinite classes may have a greater number or a smaller number of elements than the other. In this connection it is necessary to analyze the further question whether two infinite classes may exist which are not genuinely comparable as to number: but we shall not undertake to go into this question.

It is not my intention to weary you with the proof that two infinite classes may be of different magnitude as to number. It may be said, however, that the points on a line can not be put into one-to-one correspondence with the integers and that this class of points has a "greater" number of elements than the class of positive integers, in a genuine sense of the word greater. On the other hand, it is known that the number of points in space is "equal" to the number of points on a line or on a line segment of length one, however paradoxical this statement may seem. It is also true, though perhaps it is not so strange, that the number of all rational fractions is "equal" to the number of all positive integers.

If you have any inclination to feel that these statements are getting away from the province of clear thinking and are approaching the field of irresponsible

speculation, I would like to reassure you. The propositions which we have asserted will bear the closest scrutiny. They indicate merely some of the first stages by which mathematics has conquered from metaphysics a most productive region of the domain of infinity.

If you are one of those energetic individuals who like to jump from exact thinking into speculation, the definite conquests in the field of infinity will afford a convenient point of departure for such a leap. You might, for instance, inquire whether the infinite universe of nature (if indeed it is infinite) is of such an order of infinitude (with respect to the number of miles across it) as the class of all positive integers (with respect to the number of its elements) or of some other order, as, for example, that of the number of points on a straight line. If you wish, I say that you might engage in such speculation: but I shall not now attempt to pursue it with you.

The conquest of the infinite has illuminated a large section of mathematics. It has helped us in unexpected ways in making the logical foundations of our science more secure. It has led to a new understanding of the nature of functions and of the functional relation. It has given us a penetrating insight which has clarified the whole of mathematical analysis, just that part of mathematics which has been most useful to the natural sciences. The development of the theory of the infinite and the use elsewhere in mathematics of the notions to which it has given rise have been the sources of great intellectual and esthetic delight to some of the finest spirits of our race—and human experience never yields a better intellectual fruitage than such delight.

PUBLIC HEALTH PROGRESS IN CHINA

By Dr. EDWARD H. HUME

YALE-IN-CHINA

THE visitor to China who has not seen that country for ten years is probably more impressed by the development of a modern health consciousness there than by any other single factor. Modern buildings were under way, railroads and motor roads had started, education was a source of national pride even before that period; but up to 1925 there was no national sense of responsibility for the health of the people. In one or two centers there were government medical schools, the two most prominent being the Army Medical School and the Naval Medical School. There was, however, no national center dealing with problems of health and no provincial organization which could be held responsible for a provincial health program. As early as 1920 the Province of Canton had seen the need of a public health program and had established a health administration under Dr. S. M. Wu as commissioner of health. Special attention was paid to sanitation, disease prevention, public health education and vital statistics. The plans were full of promise but were not uniformly enforced. It was a beginning, however, and Canton has to-day taken its place as an active center of the public health movement. One can not date the beginning of public health activity in China with Canton and fail to record the remarkable work done by the Manchurian Plague Prevention Service under the direction of Dr. Wu Lien-teh. Trained in public health in England, it was the disastrous effect of the pneumonic plague in North Manchuria in 1910 and 1911, which invaded almost every large city in Manchuria as well as many cities in North China, that led to the calling of an International Plague Conference in Mukden and the subsequent establishment of the Manchurian Plague Prevention Service. The work achieved over a period of twenty years by this organization in the domain of plague prevention and bacteriological research is a matter of international record. Due to the leadership of Dr. Wu, the Chinese Maritime Customs began the practice of appointing health officers at the important ports throughout China. Suitable quarantine regulations were also drawn up and enforced, being eventually taken over from the Maritime Customs Service by the National Quarantine Service in 1930. A later outbreak of plague in the Province of Shansi in 1917–18 led to the establishment of the Central Epidemic Prevention Bureau in Peiping. From this center there has gone out a steadily increasing output of standard biological products which have been in great demand throughout China and have been of inestimable service in dealing with infectious diseases.

By September, 1925, a Health Demonstration Station was established in Peiping with the object of promoting public health work in the old capital and of providing facilities for instruction in public health to the students of the Peiping Union Medical College. The station provided for four branches of work—general sanitation, vital statistics, medical services and control of communicable diseases. By 1928 a health department was created in the Peiping municipality and placed under the direction of Dr. T. F. Huang. This department was conspicuous because it insisted on the registration of medical practitioners and because it was the first body to establish formal training in midwifery. Dr. Marion Yang, who had made a special study of midwifery in Europe and America, was appointed

director of the First National Midwifery School, which was opened in Peiping on November 1, 1929. Clinical material was made available in an adjoining maternity home.

After the establishment of the National Government at the new capital in Nanking in 1927, a Ministry of Health was created in 1928. Two years later its name was changed to the National Health Administration, which has continued to function under the Ministry of the Interior, with Dr. J. Heng Liu as its director. On July 1, 1935, the National Health Administration was made a direct responsibility of the Executive Yuan, thus placing Dr. Liu in immediate relationship with Mr. Wang Ching-wei, the president of that Yuan. In other words, the health responsibility of China, which was only a hope in scattered provinces a few years ago, has now been vigorously assumed by the executive branch of the government and made a matter of great national concern.

In August, 1929, the area known as Greater Shanghai was provided with a department of health. Here in the short space of three years, Dr. H. K. Hu organized a new service and divided the activities of the health department into four groups—vital statistics, health education, meat and dairy inspection and communicable disease control. After the untimely death of Dr. Hu in 1932, Dr. T. A. Li was appointed to the post of commissioner of health, and because of the sympathetic support of the mayor of Greater Shanghai has been able to amplify the work of the department and to extend it in many directions. Conspicuous at the health center is the large municipal hospital with 500 beds whose buildings will shortly be opened to the public. Provision has been made for an infectious disease hospital nearby, and an active laboratory service is already under way in the central office building of the department. Greater Shanghai is subdivided into thirteen districts, in each of which a special health station is to be created. So far, four health centers have been organized, and the work in these units is a conspicuous illustration of a modern public health program. The four districts are Kaochiao, Woosung, Kiangwan and Nantao. The commissioner of health has announced the aim of the Bureau of Public Health to be "to make the residents of Shanghai healthier, happier, more efficient, and to enable them to live a greater span of life."

In 1929 a public health department was also established in the capital city of Nanking. It is a municipal organ but is subject to the supervision of the National Health Administration. The capital is fortunate that the Health Administration includes such a group of units as the Central Field Health Station, the Central Hygienic Laboratory, the Central School of Midwifery, the Central Hospital and the Central School of Nursing. These make possible both a national and a local emphasis on health activities never appreciated before.

To quote a recent sketch by Dr. J. W. H. Chun in *The China Critic* (June 6, 1935): "It will at once be apparent that the outlook of public health work has taken on a national character. With the motive power central in the capital city, we find the provinces and large cities are undertaking new activities in public health and medical work. Newly established health departments are springing up in one provincial capital after another, and technical institutions are constantly being added so that we now have a fair number of hygienic laboratories, midwifery schools, public clinics, and municipal hospitals." Moreover, the registration of over 6,000 physicians practicing modern medicine is well under way, while the 250 missionary hospitals and several hundred other hospitals are to be counted on as a part of the total medical program.

The National Health Administration is now establishing a new outreach into the provinces. Health commissioners have already been appointed in Hunan,

in Kiangsi, in Chekiang, along the Yangtze River. Similar appointments will presently be made for the provinces of Hupei, Anhwei, Szechuan and Fukien. The Central Government has also appointed health commissioners to the northwestern group of provinces—Shensi, Kansu, Chinghai and Ninghsia. The extension of public health activities in the northwestern area has been greatly facilitated by the experienced commissioners lent to China by the League of Nations. Dr. Borcic served from 1931 to 1934 and has now been succeeded by Dr. A. Stampar, that distinguished Yugoslavian public health worker so vividly described in "The Native's Return," by Louis Adamic, under the title, "Doctor Hercules." It will be recalled that Adamic speaks of Dr. Stampar in these words: "Of the prominent men I really liked and admired only one—Dr. Andriya Stampar, a public-health expert who, in the last decade, developed in Yugoslavia a system for looking after the people's health which, to my mind, is one of the most dramatic and noteworthy achievements in Europe since the war."

In May, 1935, Dr. Stampar reported to the National Health Administration on the development of health institutions in the northwest provinces, laying great stress on the recent growth of communications in that area. The Lunghai railway now reaches from the east coast of China to the capital of Shensi Province, a distance of 1,200 miles. Motor busses run from this capital to the capital of Kansu, a trip still requiring four days. Air services, however, have been established and make communication prompt and effective. The railway line running from Peiping out along the northern aspect of the Great Wall make it possible to maintain excellent communication between the eastern provinces and that northwestern area which was until recently regarded as a sort of *ultima thule*. Some of the noteworthy elements in progress discovered in the northwestern provinces by Dr. Stampar are:

(1) The suppression of opium, which is presently to be replaced by cotton growing.

(2) The cooperation of government agencies with private banks, making financial resource accessible to the farming population.

(3) The tremendous increase in the area of irrigated land.

(4) The establishment of rural cooperative societies, there being over 1,000 in the Province of Shensi alone.

(5) The widening of streets, the provision of electric lighting plants and the water supply in the capital city of Siam at the center of Shensi Province.

Dr. Stampar sums up his report by saying, "In my opinion, the most important progress was made in the awakening of a real interest on the part of the local governments and local population in reconstructive activities."

The striking developments in the northwest during the past year may be summed up as follows:

(1) In the first place, there has been set up a Northwestern Epidemic Prevention Bureau. The Central and Provincial Governments cooperated to provide the necessary financing, both in the way of capital expense and in the way of running expense. In the bureau a large number of laboratory specimens have been examined, pupils in schools were given vaccination against diphtheria and smallpox, general dispensary activities were set under way, and a large veterinary clinic (for horses, mules and donkeys) was opened. It will be remembered that in this area there is a considerable amount of anthrax, mallus and rinderpest. Many epidemics have occurred during the last three years, and in certain counties thousands of animals have perished. Two counties report a mortality of 90 per cent. of their animals from rinderpest. In other counties there were thousands of deaths among animals from sheep pox, from foot and mouth disease, from glanders and from anthrax. The capital of Kansu Province has now

set up active supervision of slaughter houses and dairies, with special attention paid to the animals to be used under the military authorities. The manufacture of anthrax vaccine and mallein was started, and large numbers of horses were vaccinated at the request of the military authorities.

(2) Provincial health centers have been set up in Shensi, in Kansu and in other adjoining provinces. In Shensi the two chief units were a school health center and a midwifery school. The former "paid special attention to health education by means of meetings, health education courses and health exhibits. The meetings were attended by about 4,000 persons. Thirty-two teachers took the course in training for teachers. Forty-two were enrolled in other courses. The school health centers are well supplied with posters, books, models and publications for health exhibitions. From the beginning of activities of the school health center, 6,639 students were examined, and of these 5,937 students were found with remediable defects."

Special attention was given to the students in such institutions as the School of Hydraulic Engineering and the Northwest Highway Administration. Here the most prevalent disease among students was found to be trachoma, for which nearly 30,000 treatments were given during the eight months ending in May, 1935.

The second unit is the midwifery school, erected on land given by the Provincial Government with the aid of a special donation from a Chinese philanthropist in Singapore and a special grant from the British Boxer Indemnity Fund. The school has a maternity home with forty beds attached to it and is responsible for maternity and child welfare work. In the first nine months, over 600 cases were attended in this home.

In the neighboring province of Kansu, the health center included a public dispensary, school health work throughout the eight high schools of the capital city, with regular physical examination and school health training courses especially for primary school teachers. One unique experiment here is the control of midwives of the older type. In the vicinity of Lanchow the City Police Department compelled the enrolment of 37 midwives of the old wives for several months of cleanliness and prenatal hygiene. The police force itself was required to attend courses in public health education, and a number of public health nurses were employed to explain health matters to patients waiting in the dispensary. In addition to this, special health plays were given which attracted several thousand people and provided a thoroughly Chinese method of extending health knowledge.

Dr. Stampar reports how deeply he is impressed with the fine spirit and enthusiasm which have prevailed among the staffs of the provincial health centers in the northwest. Fortunately, as he points out, there has been, concurrently, a general improvement in agricultural methods in the establishment of schools and communications and in the rigorous campaigns for the suppression of opium.

Before long, similar reports on public health progress will be available from other areas in China. The Province of Kwangsi has become energetic in extending communications and education. We shall presently hear great things about its activities in public health. So, also, as the communist armies have been driven out of the Provinces of Yunan, Kweichow, and out of large portions of the Province of Szechuan, reconstructive work, particularly in public health, will take the place of the dissipation of provincial resources that has been prevalent in these three areas. Public health has become a reality in China and its opportunity is boundless.

IN QUEST OF GORILLAS

II. TANGANYIKA SNAPSHOTS

By Dr. WILLIAM KING GREGORY

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY; PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

A DAY ashore at Mombasa was crowded with colorful sights. The land itself is bright red or yellow in color; upon this is the rich green of the tropical trees, including breadfruit, papaya and cocoanut palms. Black folk swarm everywhere, some with evident traces of the blood of the old slave-raiding Arabs, whose fortress and trading-station Mombasa was. Each black face shines with an irresistible quality of quaintness or comicality, if you will, of which I never tired. Many are bovine and placid, with massive noses and mouths; occasionally the old men look crabbed and cynical; the little boys' eyes sparkle with fun and the tiny children either run away from you and squeal or come out with a snappy salute. The women vary from lithe straight amazons to weary and flaccid drudges. Noses usually are of a generous breadth and flatness but sometimes are narrower, recalling Hamites and Arabs. Thick lips usually bear a pronounced and regular "Cupid's bow." Hair is frankly woolly, innocent of the anti-kink decoctions favored by American Negroes.

In Mombasa, as in other East African places, the old Portuguese and Arab influences are now more or less overlaid by the flood of Indians, both Hindus and Moslems. The English seem to hold only the few higher offices in the banks and government bureaus, while the Indians fill most of the clerical jobs and intermediate positions between the English at the top and the blacks at the base.

Thus the old and the new are jumbled together. Ox-carts are crowded by American, French and English cars, which swarm everywhere, some of them driven by black boys with their front teeth filed into sharp points. When we asked our chauffeur for the afternoon why his teeth were filed, he said in effect that it was to make them look decent and presentable and to keep them well and fit; but the whites say that a short time ago these teeth-filing people were cannibals. Later we heard a still more dramatic explanation. When a man is sick unto death, his jaws shut tight and no one can give him water or medicine to help him in his dark hour, unless he has plenty of spaces between his front teeth.

Out in the villages where we drove that afternoon we could see frequent evidences of the dark hours of life, scattered among those spent in basking in the sun or whirling in the dance. For grievous sores afflict the people, and relatively few can or will stay long enough at or near the hospitals to get cured. Also, through some faulty technique of their midwives, umbilical hernia is widespread; most children have immensely distended abdomens, possibly from worms or malaria. Infant mortality is very high, from syphilis, yaws, blood-poisoning and many other causes.

In Mombasa and its environs we saw a few asses and donkeys that plainly spoke of North African, Portuguese or Arab influences; but on the whole, these animals as well as horses are very rare in equatorial Africa, obviously on account of the tsetse-fly and the sleeping sickness. The age of the automobile has in fact succeeded immediately upon the age of the tippoy (or sedan), while the age of the horse, when this poor beast

played so great a part in all the actions of peace and war, is conspicuously absent in equatorial Africa.

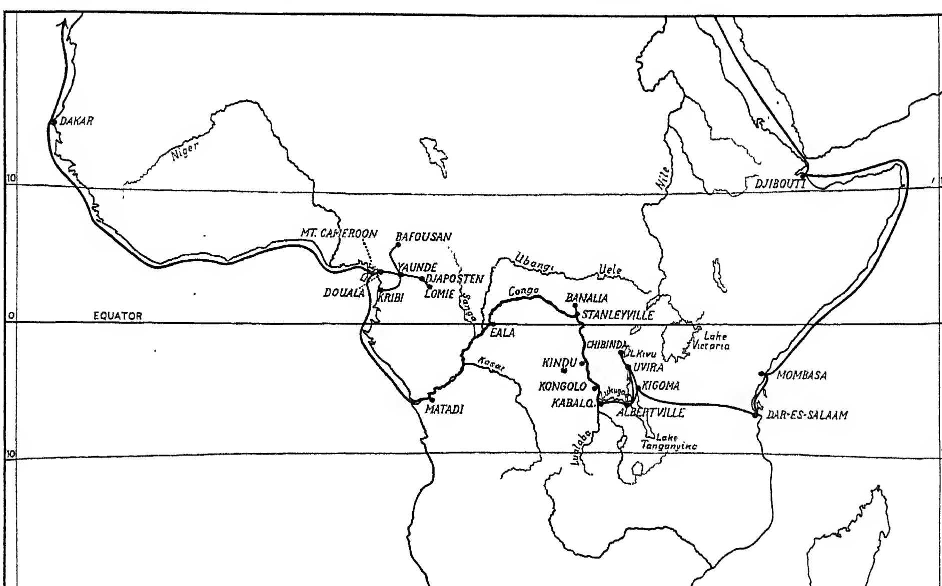
Another relic of North African, Egyptian or Arab influence we saw that day was a dromedary walking around a circular track and thus turning a millstone. During our ride in the environs of Mombasa we passed villages of thatched mud-huts, droves of goats and sheep and hundreds of Africans trudging along with loads on their heads or sitting at ease in front of their huts.

Then we drove back to the city past large walled gardens, along roads bordered with cocoanut palms. After returning to the hotel we strolled about town. In the park was a gigantic and distorted baobab tree, which was brilliant with red flowers; here also was a grove of squeaking bamboos and other strange trees. After dinner at the hotel we went back to our ship for the night.

After this foretaste of Africa we were glad enough when, two days later, our ship put in to the harbor of Dar-es-Salaam and we went ashore with all our impedimenta to the customs house.

We went to the New Africa Hotel—a relic of German East Africa (now Tanganyika Territory). This is a spacious and more or less Arabized white building with large arched porches, very high-ceilinged rooms, a central court and swarming black boys in white bag-like garments. A small tame reed-buck browsed in the inner court. Here we were obliged to stay from July tenth to July thirteenth, waiting for the bi-weekly train for Lake Tanganyika. We had arrived in the "winter" season, and the heat was by no means oppressive. In fact, the tropical African sun always surprised us by its moderation, although doubtless if we had been soldiers burdened with heavy marching equipment, we should have been less pleased with the weather.

At Dar-es-Salaam there was a great deal of tedious business to go through, especially the customs, the burden of which fell chiefly upon our leader, Mr. Raven; but I was free to come and go at will. My first walk was along the beautiful white beach of the outer harbor, which opened into the Indian Ocean.



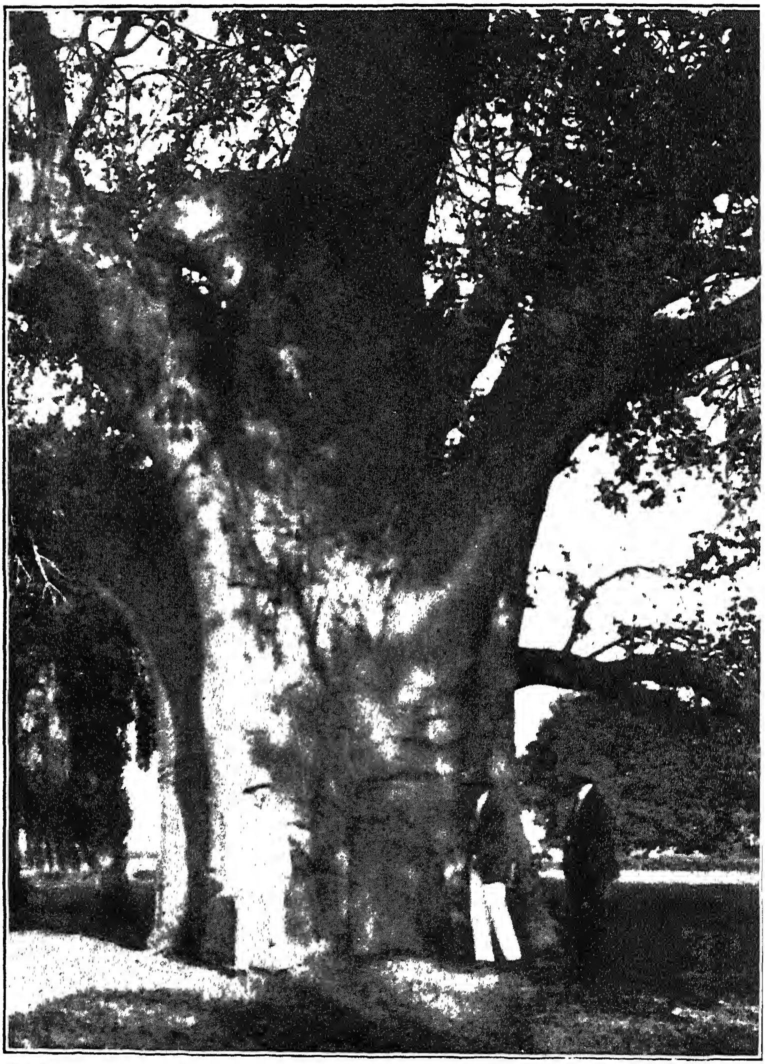
ROUTE OF OUR EXPEDITION IN QUEST OF GORILLAS.

Photograph by H. C. Raven.

CHILDREN OF INDIA AT MOMBASA.

The sun at midday was undeniably hot, but no worse than it often is in New York, and my first lone ramble in Africa was richly rewarded by various small but interesting bits. After picking up many kinds of beautiful seashells I saw small lizards chasing each other over the blackened shell-rocks. The lizards were black, dappled with gray spots, and were exceedingly difficult to see when they sat still on the rocks. They reminded me of the dead-black lizards on the black volcanic rocks of the Galapagos Islands, of black crabs on black rocks, of gray crabs on gray rocks and many similar cases of protective coloration which have come under my personal observation. At that very moment a ghostly beach-crab revealed his position by moving. I gave him a lively chase. While he was running he was easily visible, but at the moment he stopped he instantly disappeared from view, his colors blending perfectly with that of the sand. In view of many such facts it is small wonder that field zoologists believe implicitly that concealing coloration is of great value to its possessor and that it is a result of natural selection, which in the long run enforces closer and closer approximation in color to that of the environment. In spite of the fact that natural selection has to wait for small mutations to appear before selecting those which chance to lie nearest to the optimum coloration for that race in that environment, geologic time is almost infinitely long and the numbers of varying individuals that appear are so enormous that nature has had time to add to the results already achieved new successive advances toward the optimum set by the environment.

In a few minutes walk I came to a rocky place of numerous tide-pools. Here little dappled fishes, which seemed to be gobies, skippered about furtively on the greenish-gray bottom. If I stood very quietly they would slither around cautiously, but if I let the shadow or image of



Photograph by J. H. McGregor.

GIANT BAOBAB TREE AT DAR-ES-SALAAM

myself or of my hand fall on the water they sprang out of sight instantly. Much larger little fishes with vertical flank stripes were doubtless young percoids of some sort. These darted about like flies when I pretended to try to grab them. The extreme agility of tide-pool fishes has long impressed me as a fine example of keenness of sensation and perfection of locomotor control.

Above me the bird world swarmed in the clear sky. There were soaring kites and darting swifts, while a kingfisher was performing the difficult feat of hovering, before shooting down after a fish. A few dignified cranes stalked in the distance. On the walk home busy little finches, jerky wagtails and aggressive weaver-birds chattered and flitted about. The ubiquitous Africans working on the road were glad to stop and turn their broad muzzles toward the stranger. Coming to a stone balustrade near the hospital grounds, I began a lively game of hide and seek with a large lizard of the skink family. No matter how cautiously I would poke my head over the balustrade he would jerk back through the open spaces to the opposite side. He was far more determined not to be caught than I was to catch him and I left him, marvelling at his competence in looking after his own safety.

One afternoon we hired an auto and drove out in the country to a fishing-village on the coast. The fish had been brought in and disposed of, but we were much interested in finding that the people used outriggers on their canoes, which reminded us of those used by the Polynesians. It would seem less fanciful to assume that the outrigger had been invented twice rather than that the custom had spread from Polynesia to east Africa. One little girl was terribly frightened by our pointing our cameras at her, but her father reassured her with the gentleness that seemed everywhere characteristic of the Africans in dealing with their children. Some of the fishermen had beautiful large seashells, which they set down on mats before us after the manner of Hindu merchants. But our baggage was already far too abundant for our long journey across the continent and our leader disapproved of all unnecessary additions.

Next morning before breakfast we went in rickshaws to the large fish-market of the native village of Dar-es-Salaam, but nearly all the fish had been disposed of before we got there. It was a pleasure, however, to recognize many fishes of the Indian Ocean that I had hitherto known only from pictures in Day's "Fishes of India." The memory of one olive-colored fish seen on this occasion has haunted me ever since, because when I saw it I could not identify even the general group to which it belonged. Soon afterward I made a rough sketch of it from memory and am now inclined to think it was a certain member of the surgeon-fish group, which I had always wanted to see because of its evolutionary interest, as it tends to connect the surgeon-fishes with more normal bass-like types. But my observations were made so hurriedly, standing in the market in the hubbub, that I did not think to look for a concealed "knife" on the side of the tail. Hence the chief diagnostic character of the group of surgeon-fishes may or may not have been present in this specimen. But although meriting reproaches for carelessness and haste, I record the incident as typical of the joyful puzzles that Africa continued to confer upon me all along the road from the east to the west coast. Thus if I had known much more about many subjects the elements of wonder, surprise and puzzlement would often have been absent, while if I had known much less I shouldn't have been interested at all. So perhaps I was fortunate in a way not to know any more than I did, but now, after having read a great deal on Africa, its geology, anthropology and zoology, it seems that I couldn't decently have known less.

At last we were seated in the train

leaving Dar-es-Salaam for Lake Tanganyika, with all our luggage stowed in the freight car. Thus we began a journey of 780 miles westward across the territory of Tanganyika. At first we traveled up the coastal plain, a moderately fertile land with plantations of cocoanut palms; then we began to wind our way up the rocky escarpment to the high central plateau which forms the greater part of Africa.

The railroad forms a wide desolate strip. The locomotives consume a prodigious amount of wood, and the cutting and burning has devastated the country far on each side. Game used to be abundant, but now it was only by constant watching through the long hours that we were able to see a few duikers, a wart hog and its young and several small groups of impalla antelopes, some of which leaped high in the air.

The people whose villages lie along the railroad cut the trees for the locomotives and abandon the villages when the trees are all cut down. They live in round straw huts and keep a few zebu cattle, goats and sheep. They are thus the fringes of what Sir Harry Johnston calls the "cattle-keeping aristocracy," who are straight-featured, handsome negroids, derived mostly from the southern Abyssinians mixed with the forest Negroes. The women, as usual, till the fields and fetch the water. Little boys drive the cattle home from the stubbly pastures. On this plateau the flat-topped acacia trees dominate almost as much as the eucalypts do in Australia.

Then we began to move down into the vast but shallow depression which is known as the eastern rift valley. This is, of course, part of an enormously long system of troughs, lake-beds and bordering mountains that straggles all the way from south of the Zambesi up through the African great lakes to Palestine.[1] From the hazy silent plain rounded hills or kopjes slowly appeared to rear themselves in the distance.

Soon we were in the midst of a world of shattered rock, the battle-ground of titans; in such a place Prometheus chained might have defied the utmost wrath of Jove, or Satan's troops have fought against the angels of light. Here were no puny human bulwarks but battlements of granite mountains strewn with mighty boulders; and great was the confusion and the desolation thereof. Low hung the billowy clouds above, in legions numberless to man; and beyond all the illimitable blue. Straining over the iron gate at the end of the train, I lift up mine eyes unto the hills and my spirit is filled with awe and exultation.

Up the other side of the rift valley the train wound its slow way, spiralling up through rocky passes to a still higher plateau, where we could look back at right angles to the very long straight track where we had crossed the plain. For a night and a day we traveled over this plateau region of incalculable antiquity. According to the geologists, this plateau has never been covered with the thick mantle of marine rocks such as are found in Europe and Asia. Also it has been fractured and broken into huge block-like areas which have suffered warping and vertical displacement.[2]

We continued on and up and over the mountainous plateau on the other side of the eastern rift valley until at last we reached the headwaters of a river that flows downward toward Lake Tanganyika. Following down this valley, which grew more and more fertile and green, we descended toward the lake. At last, after two nights and one day on the crowded train, we passed through a break in the rim of the hills on the east side of the lake and suddenly came out at Kigoma on the east shore of Tanganyika, one of the most beautiful of the African "great lakes." But about this more later.

We stopped beside a huge recently cut embankment, vividly red and flanking a spacious, smooth red plaza with broad,

[1] J. W. Gregory, "The Great Rift Valley."

[2] Bailey Willis, "Living Africa," 1930.

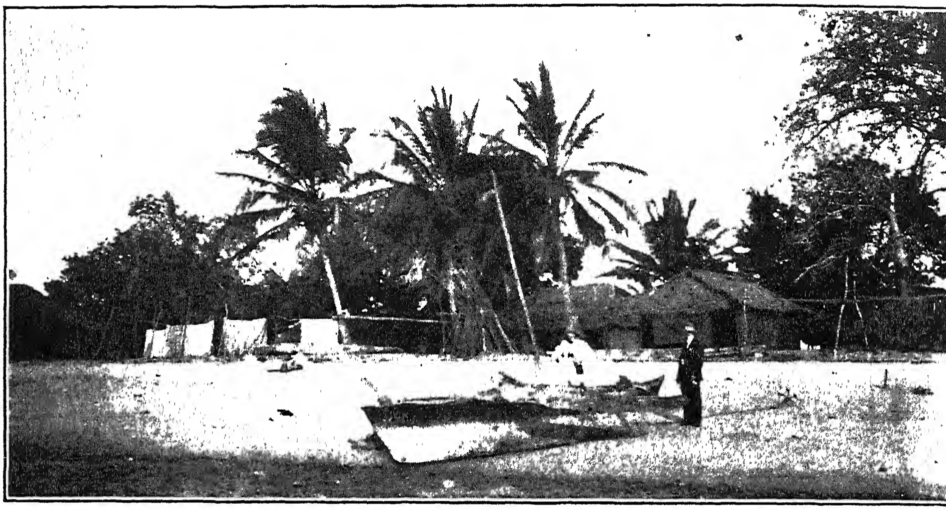
Photograph by H. C. Raven.
CONGLOMERATE AT KIGOMA AT ENTRANCE TO BAT CAVE.

freshly whitewashed trimmings. What a hubbub! A swarm of comical blacks rushed into the car, jabbering and struggling to seize and carry off our baggage on their thick-topped heads. Imitating the usual manner of the white man in Africa, I yelled at them, pushing all of them back, and made one of them pass one piece of hand baggage after another through the window to those waiting outside, where Raven and the others lined them up. In a few moments we started off in a procession to the imposing white railroad station that rears itself high athwart the end of the railroad. All our personal baggage was accounted for, but the baggage-car containing our extensive equipment would not arrive until later, perhaps the next day, perhaps after our boat had left Kigoma!

Then we went up the long red hill to the "Greek hotel," which, fortunately enough, was already jammed with travelers. Fortunately also the *Baron d'Hanis,* the big lake steamboat, was tied up at the wharf for repairs and the captain very kindly gave us permission to come on board as passengers and occupy cabins for the next night or two until a smaller steamer should be ready to start on its trip up the lake. The head steward kept the galley going even when the vessel was hauled up on the dry dock.

For a while we stood outside the hotel and watched men, women and children coming up the hill, many carrying loads on their heads and walking as straight as arrows. Even a bottle or a can of tomatoes would be poised as steadily as a load of fifty pounds.

Here comes along the red hill road a gang of dusky savages with goatskins draped over their shoulders. They are carrying a heavy load of corrugated iron

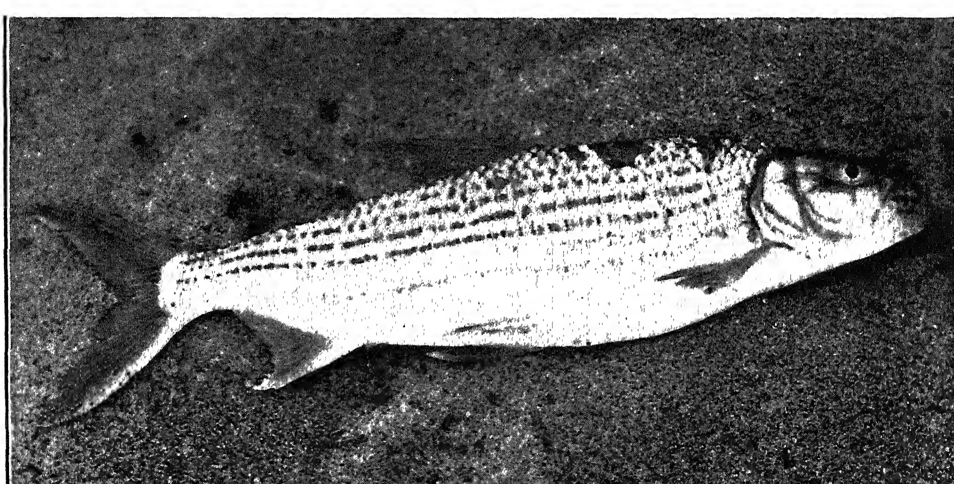


Photograph by J. H. McGregor.

BOAT WITH OUTRIGGERS, DAR-ES-SALAAM.

sheets, which are used to roof most of the white men's buildings in equatorial Africa. Strange to say, their tongues are silent for a second or two, only the soft tread of their feet being audible. Suddenly, as the load sways back and forth on their patient heads, some one gives out a quick but mournful theme—then the chorus breaks in, rippling and swishing back and forth in unpredictable antiphony. I listen entranced. What words could be adequate to such inspired music? Is the song itself as sad as "Old Black Joe" or as stirring as "Old Man River"? Alas, no! The words are probably trivial and with little dramatic value; at least, so I was told by a student of African music.

One moonlight evening I stood still and listened intently to the men who were loading logs of firewood into the boiler-room of the lake steamer. The black



Photograph by H. C. Raven.

THE TYRANT OF AFRICAN WATERS (HYDROCYON CF. LINEATUS.)

chorister on the wharf grumbled a bit as he lifted a heavy log: *"Heave ho-a"* would be the meaning perhaps of the magic words that he sang; down thumped the log on the steel floor of the pit.

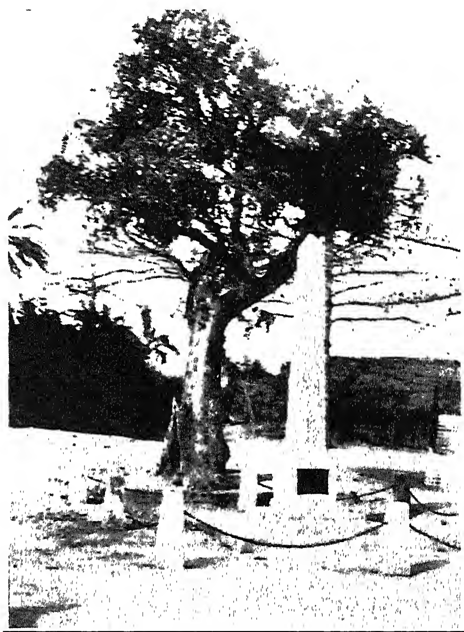
"Garrump-a lunk-a," or words to that effect, responded Shiny-eyes below, who kicked the rolling log along.

"Whumph-ala bam," moaned White-teeth, as he chucked it on the pile. So was their labor lightened and their humble hearts gladdened by the divine Muse.

While they were singing I could imitate them, at least to a certain degree, but afterward their refrain soon joined the long sequence of "Lost Chords" which now haunt my reveries of Africa. What an opportunity there is for some future Dvorak to compose an African symphony, weaving the songs of men that carry burdens and of women that dance to the rumble and thumping of big and little drums.

While we were waiting for our tardy baggage-car, as well as when we returned to Kigoma several months later, I took several walks around the bay, rejoicing in the opportunity of walking on the shores of Lake Tanganyika, which teems with interest to the naturalist. At the radio station there is a promontory composed of massive gray metamorphic rocks, part of the excessively ancient African continent. The shore is covered with large angular fragments which are so dense that they have withstood the action of the usually quiet waters; the shore in this place is literally without sand.

Here I found the following fragments among the scant flotsam and jetsam: first, half of the lower jaw of a hyena, which was easily identifiable by its massive curved lower border and huge cutting cheek teeth; next, there was a bony plate, evidently from the nape of the neck of a large catfish; next, an old nest of some fish-eating bird, containing fragments of fish skeletons too small for identification. The visible life on the rocky shore at this point was extremely scant: no flies, no crabs, very few mollusks. In the pools of water in the foreground I found a small olive-colored water-snake, which insisted in crawling out of an old tin can in which I placed him, even after his spinal cord had been severed just behind the brain. Apparently the reflex systems in his spinal cord were sufficient to keep him trying to climb out of



Photograph by J. H. McGregor.

THE MANGO TREE AT UJIJI

WHERE STANLEY MET LIVINGSTONE IN 1871. THE MONUMENT COMMEMORATES THIS EVENT.

that confined space. I treated him a bit gingerly, as the chances that he was poisonous were fairly good. Recently I learned that this little snake represents a rare water-living species of cobra, which hides under the rocks on the shore of this lake.

The large pools and open water near shore were inhabited mostly by a single species of very abundant, small bass-like fishes, swimming in schools, which I watched for a long time. The water was so clear and rippling in the early morning sunshine that I took off my clothes

Photograph by E. T. Engle.

DR. RAVEN AT UJIJI. HE IS ABOUT TO TOSS A SMALL COIN TO THE BOYS

and went in for a swim, being careful, however, to remain quite near the clear water by the rocks. Afterward my enthusiasm for bathing in the lake was somewhat dampened by finding the scattered bones of a large crocodile right near this spot.

On the shore of the lake I found a large cycloid fish scale, which I afterward learned was probably possessed by one of the big characin fishes, such as *Hydrocyon* (p. 512). But all fish equipment was still packed and in bond.

After my swim I went southward along a beach where the waves had ground the rocks up into very coarse sand. On the way I passed across fields where there were enormous grasshoppers in green, red and yellow. Here also dense ledges of nearly horizontal, dark purplish-red sandstone concealed the old crystalline rocks, which doubtless lay beneath them. This was the first time I had seen any rocks of this wide-spread system (Lualaba-Lubilash), which corresponds in a general way to the Karroo system of South Africa.[3]

Going on a short distance to the south shore of the bay, I came to a huge promontory called the "Elephant's Foot," which juts out into the lake. This is formed of a conglomerate containing untold thousands of oval pebbles, many about as big as eggs. This conglomerate seems to overlie the formation of horizontal sandstone exposed near by. The pebbles in it have been rounded by ancient streams and then imprisoned in the mud, and the whole has hardened into rock. Some of them were now weathering out of the rock and being set free again on the shore of the lake. Probably this conglomerate is of recent age, as the pebbles are not solidly fused in it. The whole surface of the rock toward the lake is beautifully rounded, probably through the combined action of rain and waves.

[3] A. C. Veatch, "Evolution of the Congo Basin," *Geol. Soc. Amer.*, Mem. 3, 1935.

The promontory is cleft by deep incisions, one of which extends far inward as a sort of cave. I crept quietly into this dark passageway and was delighted to find it thickly populated by large bats, which flitted over my head to the darkest niches behind and above me. One or two bats still clung to the wall that was partly illuminated by the light from the passageway and as soon as my eyes became accustomed to the semi-darkness I could see clearly that they had enormous ears and pointed muzzles. Later when we all visited this spot together we secured several of the bats in a net and Dr. McGregor got a cinema picture of one of them.

While we were at Kigoma, three of our party went over to Ujiji, a village near by, which is famous as the place where Stanley met Livingstone in 1871. Here the native population showed considerable Arab intermixture, as this was one of the great Arab headquarters for the slave trade.

After a two-day wait at Kigoma, our baggage-car came in and both the English and Belgian customs officials were exceedingly helpful in speeding it through the custom houses. In the evening we went on board the *Urundi,* a small lake steamer, and thus entered officially into the vast empire of the Belgian Congo. The boat was crowded with passengers and there were no staterooms available, so we spread out our bed-rolls on the foredeck just behind the anchor chains and winch. It was a moonless starry night, and after a somewhat too obliging passenger with an enormous accordion had exhausted his repertory—to say nothing of us—we lay down and slept till dawn.

Numerous bush-fires dotted the low mountains along the lake with dark glowing spots. These bush-fires, as we learned, occur almost everywhere in the highlands of Africa during the dry season and have inflicted incalculable damage to the forest and native fauna. As they have probably been going on for hundreds of years, they have left thousands of mountain-sides bare, except for the coarse grass and thick underbrush that spring up quickly in their wake. The fires are mostly set by the natives, both after the forests are cut away for their timber and when new crops of underbrush cover the pastures.

All that night and the next day we sailed north along this great and exceedingly deep Lake Tanganyika, the surface of which is about 2,680 feet above sea-level. The fiord-like valley which it fills is part of the Western or Albertine rift system, which, as already stated, extends southward into Rhodesia and northward through Lake Albert to the chain of lakes that passes northeastward through Abyssinia to the Red Sea. In the waters of Tanganyika, as we later found, live many organisms of apparently marine affinities: a fresh-water medusa (which we saw floating in schools near Baraca), oysters, allied to marine types, small crabs of an essentially marine family, cichlid fishes belonging to a family which is rather closely related to the marine percoid fishes, and many other organisms.

How did these once marine creatures get into this now land-locked lake, so high on the tableland of central Africa and so far from the nearest sea-coast? The answer, according to most zoologists and geologists, is that parts of the great rift system of fiord-like depressions were originally connected with the Indian Ocean, either in the northeast, as the Red Sea now is, or at the southern end along the continuation of the rift system below the recent Zambesi River. Relatively recent earth movements and volcanic outpourings have perhaps pinched off the ends of the system in Africa and left a chain of separate lakes; in these the water has gradually become fresh without destroying all the marine creatures that had flowed in from the ocean when the great rift was established. It

should be noted, however, that Professor MacFarlane, of the University of Pennsylvania, in his book on the "Evolution and Distribution of Fishes,"[4] states that none of the organisms mentioned above has been derived from marine forms, but rather that the reverse has happened, namely, that the really primitive organisms are to be found among the fresh-water fauna. So far, however, as his argument rests on the evidence derived from the fishes, I find myself in detailed disagreement with his interpretation of the facts.

About noon of the next day our boat anchored off Usumbura at the northern end of Lake Tanganyika and began to transfer some of its black passengers to a smaller steamboat, which took them to the wharf, and at the same time to take on other passengers, both black and white. A fairly stiff breeze was blowing up the lake, and the little boat bobbed up and down more quickly than ours did. This lack of synchronism produced effects upon the poor debarking natives which were both amusing and thrilling to us, but about which they were not at all enthusiastic. Imagine having to pass nearly all your household effects by hand from the big boat to the little boat, or *vice versa,* in that bobbing sea! But how bravely the women stuck to their job of handing the babies and gourds and matting-rolls up or down to the men, who grabbed them and pulled them whichever way they were going. The babel of it was indescribable. One poor man got imprisoned behind a heavy rope that tied the smaller boat to ours; as the boat swung around it pressed him into a pile of baggage and threatened to cut him in two at the waist. Anybody but a native would have been at least breathless, but after emitting sundry emphatic remarks, or volumes of remarks, he shook himself like an indignant rooster and climbed off the boat. Meanwhile the mate was cuffing the dumbhead that was responsible for the mishap. From the swaying upper deck I was rejoicing in a nearly top view of some of the widest, most imposing noses I had ever seen, some of which even a "missing link" might not disdain to own. These people were soldier-police and their families, detailed to stop a while at this town and make the prisoners work on the roads. If they had been Sicilians, somebody would probably have been knifed as an expression of resentment; but being Africans, after the uproar they counted it all as part of the day's work and forgot it.

From Usumbura our boat turned to make an arc across the lake to Uvira, crossing the rapidly increasing waves. Every day when the clouds do not cover the higher mountains toward the northern end of the lake, the mountains become heated and a strong current of air rises from them, sucking the cold air above the lake toward them and stirring up quite a choppy sea. During this particular passage of the boat the waves were far too big for the comfort of the crowded passengers and the next hour was a time of gloom and misery of which the less said, the better.

Eventually, however, we passed into the quieter water in the lee of the mountains and soon we tied up at a wharf at the foot of a steep mountain of yellowish-gray crystalline Pre-Cambrian rocks. To come into view of a geologic formation that is new to me is always exciting and I was impatient to climb up the nearest of these jagged peaks and get a view of the lake and surrounding country. But it was then near evening and I had to restrain myself.

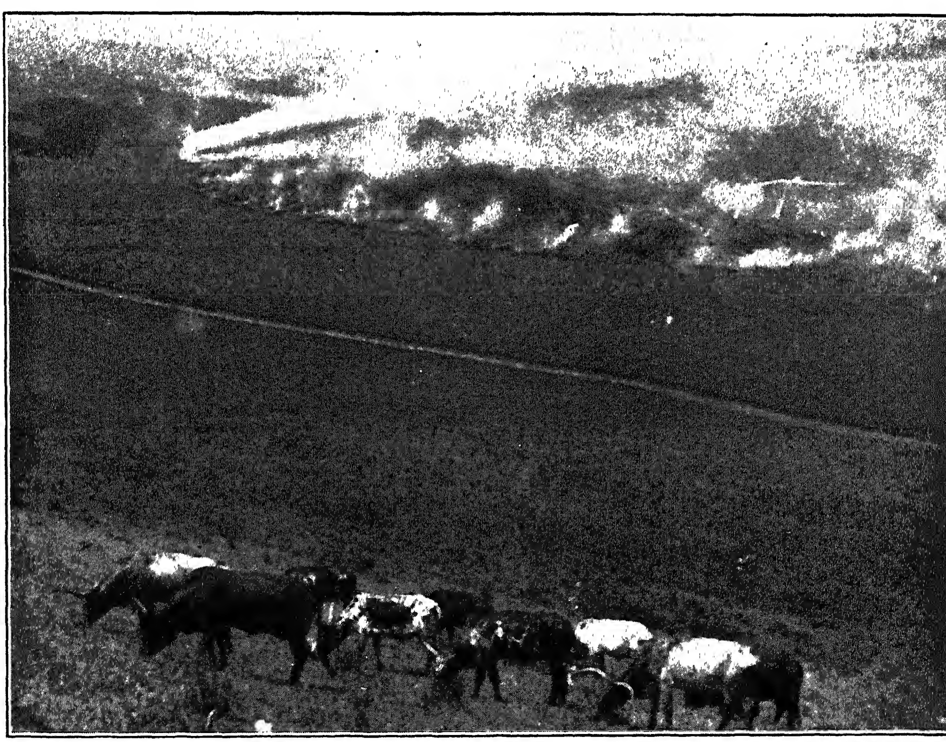
After a very long wait for our baggage and for a camion, we were whirled off in the night to one of the world's worst hotels. The one room available was fairly large and had four good-enough beds in it, but it opened on the barroom, where the American phonograph tried to outscream the full-voiced revellers, who were always celebrating some holiday.

[4] Macmillan Company, 1923.

The management paid us the compliment of feeding us as if we were mighty men of valor, who must have nought but strong meat and plenty of it. Apparently a whole herd of ancient he-goats had been purchased for our benefit and the "cook" performed further wonders in cooking the meat to degrees of toughness never before dreamed of by our unfortunate teeth. Three times a day we faced the ordeal and this went on for a long week. The manager of the "hotel" was said to be a Greek, but whatever he was he could earn good wages as one of the lesser pirates in Hollywood. There were next to no servants visible, only two miserable little black boys; one boy, named Moki, was arrayed in the most grimy of shirts and short pants; the other little boy wore only a native toga of goatskin but with great dignity. Their cooking, dish-washing and waiting on table had best be left unsung. The manager explained that he could get no other servants, as all the able-bodied men were at work building the new hotel next door. Nobody thought of hiring Negro women as hotel servants. Their place was in the home, where they did the farming and other domestic tasks, including some very sketchy cooking and housekeeping.

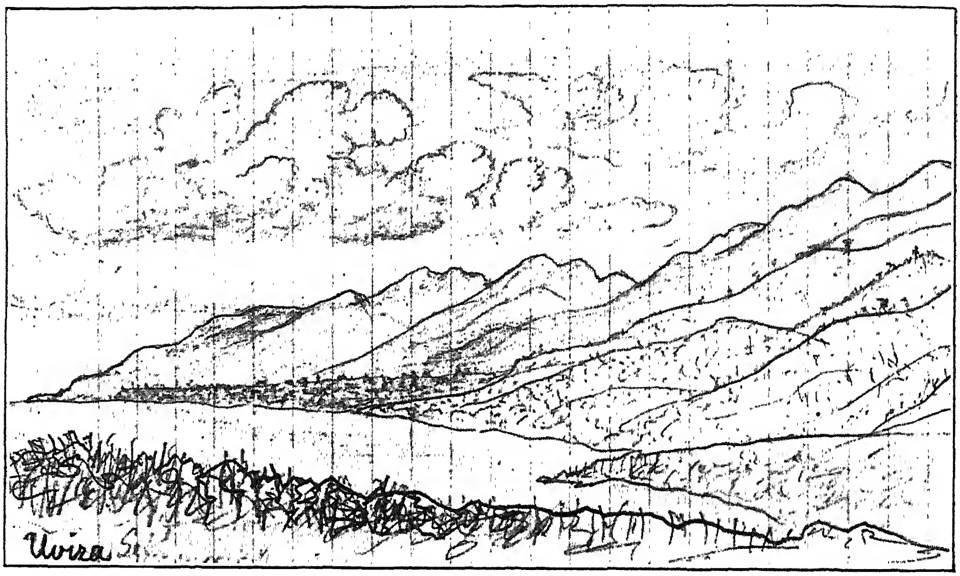
At meal times Moki, who had about enough brains to admit him to an imbecile asylum, was the official scapegoat of the establishment. Whenever any one forgot to put a knife or fork on the table or to serve a waiting guest, it was always Moki who was roared at by the pirate-manager. Moki took all the verbal abuse with the stolid placidity of his race, however, and went about his work with an air of dogged resignation. Moreover, Moki had, in my eyes, a great redeeming trait—his muzzle strongly reminded me of that of the pig-tailed macaque.

A week later, when we left the hotel,



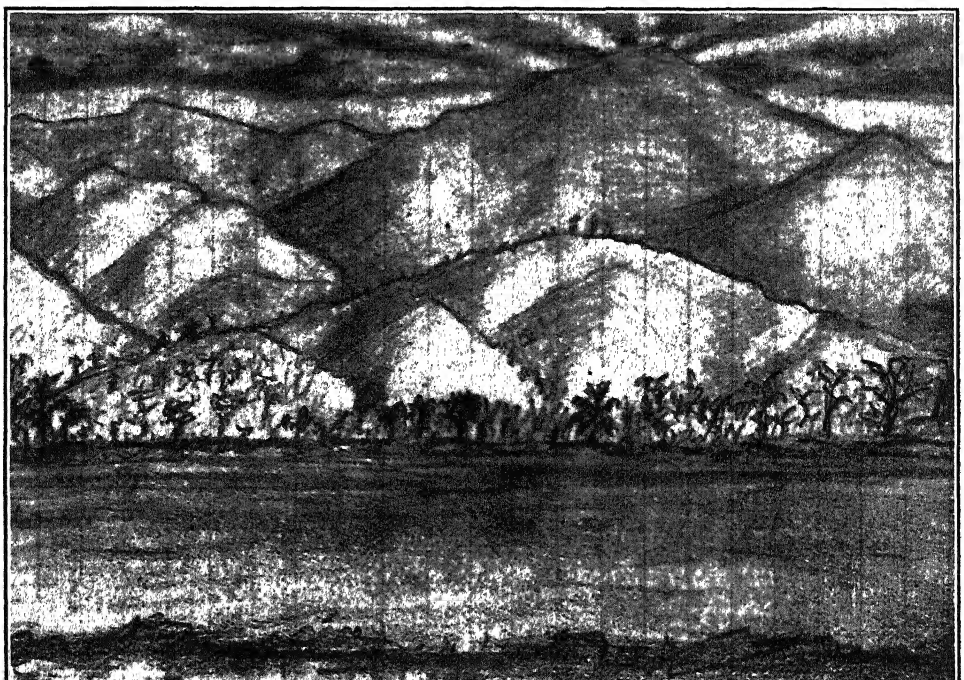
Photograph by H. C. Raven.

BUSH FIRE ON THE HILLS AT BUKAVU, LAKE KIVU



Sketch from author's note-book.

DRAINAGE SLOPES AT UVIRA.



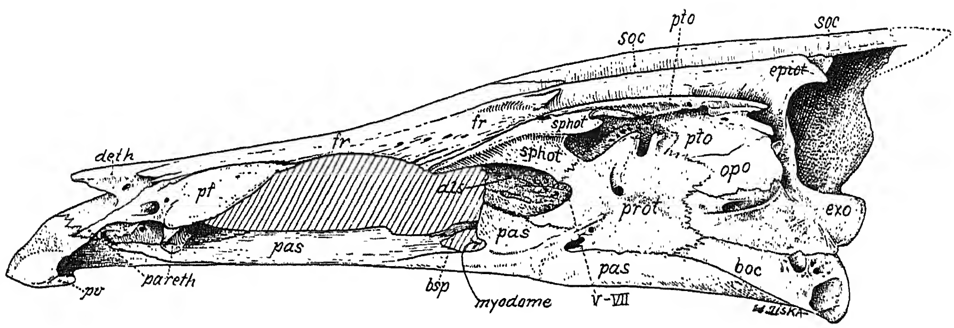
Sketch from author's note-book.

SUNSET AT UVIRA.

we took pleasure in giving Moki, by way of consolation, a tip of enormous size for that part of the world. We have no doubt that he had sense enough to keep it out of the manager's clutches. We never observed that the manager struck Moki, as under the benign rule of the Belgians there is a heavy fine for striking a native and doubtless all the natives know it.

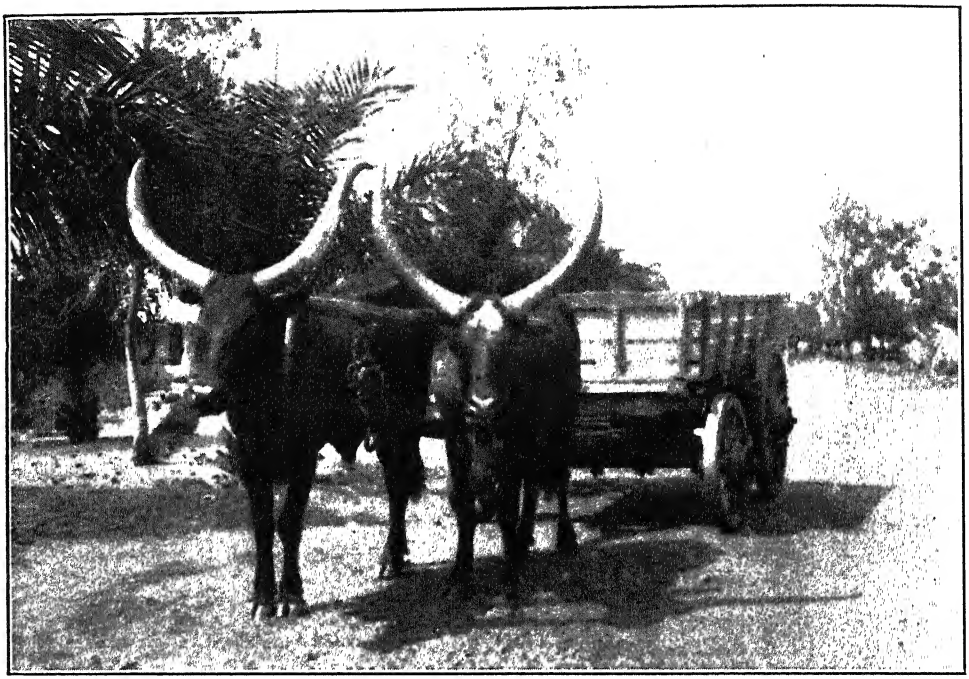
Next morning after our frugal breakfast we went out to see what Uvira looked like in the daytime. Like many other towns in the Congo, it is growing very fast in anticipation of the completion of the railway which is now being built to connect Uvira with the towns to the north on Lake Kivu. Next door a swarm of naked little black boys were gliding forward, carrying little pans of water or small loads of brick on their heads to the masons, who moved with the celerity of half-melted asphalt. The little boys have spindly legs, enormous abdomens and huge, languorous eyes; their faces and bodies are daubed and dusted in the most ludicrous fashion with the mud and plaster amid which they move.

A yoke of oxen has just brought a load of sacks of cement for the building. The oxen have enormous horns which rise up almost vertically above their foreheads. (Afterward I learned that these very long-horned cattle are similar to those figured on the Egyptian monuments and are said to belong to the same species.) They stand there sleepily, submitting most willingly to the services of two industrious hens, who are eagerly picking off the flies and ticks that cluster on the legs, necks and bellies of the oxen. The off-ox even lowers his head, turns it on one side and plainly invites the fearless hen to relieve it of the pests that cling around its eyes. I was full of wonder at this miracle of apparent intelligence on the part of the ox. How did it learn this trick? On many other occasions, however, the answer came readily. African cattle generally, both wild and domestic, are attended from calfhood onward by beautiful white herons, which perch on their back or stalk deliberately about on the ground, and by flocks of pert little ox-peckers, which flutter about and take the most surprising liberties with their gigantic friends. Once we saw an ox-pecker cling to a cow's head and literally climb into her ear in its eagerness to help itself to the delectable feast of flies and ticks.



CRANIUM OF THE NILE PERCH

On Sunday, July 21, 1929, when we were somewhat dismally waiting on the hotel veranda for our Sunday dinner of goat's meat, we received a brief visit from a so-called pygmy, who seemed rather to be a midget or ateleotic dwarf. She was a little old lady exactly three feet, eight inches high, and very fussy and particular in her light calico dress. She had a tiny straight face, an infantile long head and delicate limbs. In my in-



Photograph by H. C. Raven.

LONG-HORNED OXEN AT UVIRA.

nocence I offered her a large safety-pin, hoping that she would thrust it through the base of her nose, but she handed it back with a superior air and held out an insistent palm for francs. She then did a few very formal and deliberate turns and posed for her photograph, standing beside one of our own blond Nordics, winding up the performance with greedy appeals for more francs. She looked ancient, but one of the guests assured us that she could not be more than forty years old, because she said she remembered a certain famous Arab raid that happened when she was a child.

That afternoon I strolled down along the lake shore near the wharf where the boats from Kigoma come in. At that point a stream which has cut its way down through the crystalline mountains has discharged on the lake shore an enormous load of large angular fragments of schist, containing mica, and blocks of feldspar. The waves have had but little effect on these hard fragments, or probably they have broken off all the more friable pieces, shoved them along and ground them up, distributing them as coarse sand on the shores near by. In certain spots these angular fragments are being cemented together by a natural cement into a massive and very hard breccia. At this place I did not know which attractive route to follow: whether to push my way up the rocky gorge, which was highly alluring in its wild confusion and grandeur, or to follow along the shore, which was already yielding its provocative traces of nature's wonder-working.

Here are some of the things I saw along this shore on this and other walks. First, the backbone of a large fish, evidently belonging to the enormous group of the "spiny-finned" fishes; but to which one? A few yards further came the answer in the shape of a sickle-shaped preopercular bone with several large cog-shaped projections on its hinder border. Surely this must be my old

friend *Luciolates* or some near relative. Then a little way further on and there is a glistening white, perfectly cleaned skull of *Luciolates,* which I eagerly grasp, for what osteologist would despise such a gift! In fact this skull afterward proved exceptionally valuable to me, since it so clearly illustrated the details of bone architecture in a typical fish skull. Then I pick up two very beautifully sculptured bony scutes, each about two inches in diameter, which have weathered out from the leathery back of some large crocodile. No wonder the natives keep very close to the shore when bathing! Then many small crabs, the same species as those at Kigoma and closely related to marine types. Then swarms of tadpoles in the tide-pools, getting ready to take their places in the Uvira night choir.

On another occasion I came to a village near the shore of the lake, where most of the folks are basking in the sun, but here are some small boys standing in the water and fishing. These young rascals have been fishing on the Sabbath day with a pole, a bit of string, a bent pin and worms. They come near and show me tiny baskets or old tomato cans containing gorgeous little cichlids and most comely young *Luciolates*. Recklessly I spend my money for each lot, getting six or seven different species for a few Belgian francs (1 franc is about 3 cents). The boys know I am crazy, to pay so much for so few mouthfuls, but I rush off with hands and pockets full, to sketch some of these fish while they are fresh and to get them in formalin soon afterward. I do not mind in the least that probably none of them are "new to science," as the fishes of Lake Tanganyika have been described by several authors. They are all new to me anyhow, and give me my first field-introduction to this famous African family of cichlids.[5]

[5] By a strange chance, however, most of the small fishes which Mr. Raven and I collected in this way proved to be new to our collections at the Museum, and one of them was later described as "new species" by our colleagues J. T. Nichols and F. La Monte.

One afternoon I started northward along the road toward the head of the lake, looking however constantly toward the bare mountains on the left for a favorable place to climb up one of their lower spurs. First I pass through a small and a very soiled-looking settlement of Indian merchants. Here several long-bearded patriarchs with sickly, pallid skin and cold eyes await Nirvana; but meanwhile they despoil the heathen blacks.

Next I come to extensive brickyards, where the natives make huge piles of bricks from the red clay and bake them. Passing through this village on my way up the path toward the mountain, I find many men sitting leisurely in front of their round straw huts and doubtless discussing weighty matters, while the women are out at work. One elderly man starts after me. I know he wants to serve as my guide, but there is no way to go but up and nowhere to come but back, so I wave him off. Blandly and doggedly he follows my footsteps, as many another native is to do in the months to come. So at last I renounce the selfish hope of enjoying the view all by myself and hand him my coat to carry.

The bush fires have swept away almost everything but a few Euphorbias, some of which grow to imposing size and look like gigantic, many-branched candlesticks. In the pale stubble at our feet I find a small "praying mantis," which is of precisely the same color as the straw upon which he rests. I am constantly on the lookout for a snake, partly because I want to see one, partly because I want to see it first! But only a small cast-off snake-skin rewards my search and I attribute to the bush fires the apparent rarity of snakes which I observed almost everywhere we went in tropical Africa.

As we zigzag upward over the yellowish crystal rocks and blackened fields new wildness and grandeur are revealed; the mountains in the rear come into view and lift up their summits, higher and

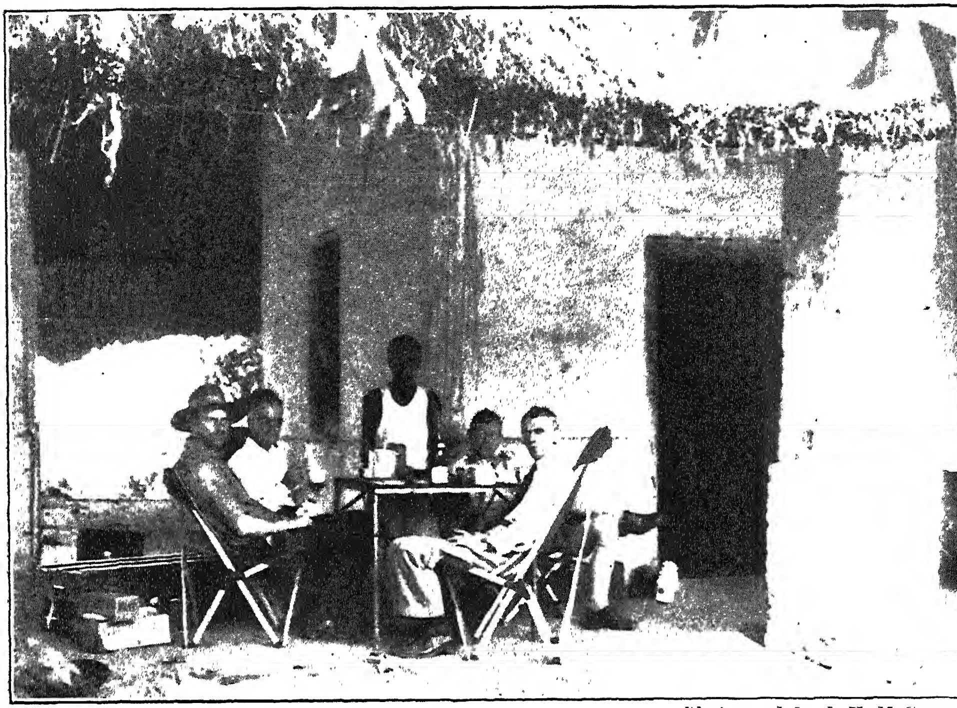
higher; those in the foreground send one jagged crest behind another in long slopes toward the silver lake. I sit down for a while and make a desperate effort to record a few of the crowding mountain profiles in a very crude sketch in my notebook. (This was the first of many that I made on our journey across Africa. No matter how crude they are, they now possess magical qualities since they can instantly carry me back to some soul-filling scene of African mountains and rivers.) I get up and we go on upward; finally we reach the steep shoulder of one of the lower mountains; the sun begins to go down and with half the sky for his background pours forth his most brilliant reds and greens and yellows upon the heaped-up clouds, the jagged mountains and the shimmering lake. The celestial color-symphony mounts to almost insupportable heights and then slowly recedes into myriad purple waves. Reluctantly the spectator descends the open mountain side to the highroad and dismisses his faithful guide with a generous reward.

During the next ten days at Uvira Raven was constantly busy with many tedious but unavoidable duties. First, as Uvira was practically the port of entry into the Belgian Congo, he had to go over his lists of equipment and assign a fair valuation to every foreign article we were bringing into the country, and the customs officer had to ascertain what import tax should be levied upon each article. The whole amounted to many thousands of francs, a sum which, however, was only paid on deposit, practically all of it being refunded when we left the Belgian Congo.

Meanwhile the administrator of the town of Uvira had very kindly placed at our disposal a commodious house and the adjoining grounds, which belonged to the Government. The house had brick walls coated with whitewash; there were broad cool brick verandahs and a thatched roof. Up to this time (July 24) our entire camp equipment had been, as it were, in bond to the customs of the different countries through which we traveled and we had as yet used only the things that were in our personal trunks and hand baggage. At last the time had come to open up all our camp equipment. After our things had been moved from the Customs House to our new temporary home, Raven, assisted mostly by Engle, selected the stuff necessary for our coming trip into the mountains west of Lake Kivu, storing away the supplies for our future trip down the Congo. For the present trip hundreds of things were necessary: for injecting and preserving specimens, for photography (movie and still cameras, several kinds of negatives, chemicals, portable drying frames, etc.), medicines, firearms, ammunition, bedding, folding chairs, cooking utensils, etc., etc.—all to be packed, catalogued and arranged for accessibility in boxes and bundles just big enough to be carried on a black man's head up mountain trails.

Then as soon as we could obtain three good boys as servants, we set up our camp beds and mosquito nettings on the porch of this house and took joyful leave of the Greek and his hotel. We immediately celebrated Dr. McGregor's birthday with a fine camp dinner, including excellent soup, roast chicken, salsify and bacon, home-made bread, white wine and real tea—a refreshing contrast to the devastating fare of goat's meat at the hotel.

There were many beautiful mango and other trees on the grounds in front of our house, which overlooked the lake shore. Here in the daytime fair-sized agamid lizards with spikes on their heads raced up and down the tree trunks and ant-lions laid in wait for their prey in conical depressions in the ground. I had an unfortunate experience with one of these lizards while photographing him—unfortunate for the lizard, that is. The poor thing was tied with a string and in



Photograph by J. H. McGregor.

WE DINE CHEZ NOUS AT UVIRA

its frantic struggles to escape, snapping its jaws and running hither and thither, it soon became sunstruck and died. I should have remembered that a reptile is much inferior to a mammal in its ability to keep the body temperature from rising beyond the danger point.

At night we would creep out under the trees and then, turning on our flashlights and looking along the barrel, we saw at different times the lamp-like green eyes of a small antelope, the glowing red eyes of a civet cat, the small green eyes of fruit bats. The latter flitted about in great numbers, their black wings outlined against the moonlight.

As the mountains cooled off, the air upon them grew heavier than that above the water and a cool breeze swept down toward the lake, which made our blankets very acceptable at night.

In one of the inner rooms of our house Dr. McGregor and the others developed their photographs at night, disputing possession with the enormous cockroaches that swarmed over the walls. McGregor was delighted with these insects, which showed many stages of development from the egg upward. They are, it is true, among the most ancient of "living fossils," remains of their ancestors being found in the rocks dating from the Carboniferous period; nevertheless, I was slow to give up my ancient grudge against them. Raven was inclined to take McGregor's side of the argument, but later when, in the middle of the night, one of these ravenous beasts had given him a good bite on the top of his head, thereby marring its orb-like splendor, his manner toward them (to judge from his remarks) seemed less cordial and appreciative. Ingenious devices had to be adopted to protect the washed and drying negative strips from being nibbled by these voracious animals.

While we were at Uvira we had the pleasure of meeting Mr. G. B. Murphy, a

young man who had been sent from the department of birds in our Museum to conduct collecting expeditions into various parts of equatorial Africa. He was just returning from the mountains to the west of us at Uvira and had secured there some excessively rare species of birds for which he had been especially searching. He told us one incident of his journey that illustrates some peculiar traits of the African character. He had arrived at a certain village, where he had requested the chief to supply him with porters. The chief had assembled the available men and ordered one after another to go with the white men. One big man said "No, I will not go." "You will not?" asked the chief. "No, I will not." At the chief's orders he was seized, bound and lashed until the blood ran from his back. "Now will you go?" asked the chief. "No, I will not," replied the man. Again he was beaten, more cruelly than before. Again he was asked whether he would go, and again he refused. It was not until the end of the third beating that his spirit was broken and he said he would go. In a day or two, when they were ready to start, this big man stood in line, took his load on his head and served well throughout the trip, bearing no grudge against the white man.

At last our arrangements were sufficiently completed at Uvira and it was decided that Dr. Engle and I should go ahead to Bukavu (Costermansville) at the southern end of Lake Kivu, while Raven and McGregor would follow in a few days. Although Lake Tanganyika is one of the highest lakes in the world, Lake Kivu, the next one to the north in the series of Africa's Great Lakes, is some two thousand feet higher. At the southern tip of Lake Kivu the surplus water of the lake drains off to form the Ruzizi River; this river breaks through the volcanic mountains south of the lake and runs southward into the northern end of Lake Tanganyika. The Belgians, who are the greatest road-builders since the Romans, have constructed a good road along the Ruzizi Valley so that commerce can flow north and south, between the Belgian Congo and the rich countries around the headwaters of the Nile. Camions driven by Portuguese and Negroes make this trip two or three times a week.

At about 4 A. M. on July 25, 1929, a big camion stopped at our house in Uvira, our baggage was quickly stowed aboard and Engle and I climbed up into the seat with the black driver. As we bounced over the rocky road before daylight our flashlights revealed many natives, both men and women, carrying huge loads of cotton and other products in great baskets on their backs or in bales on top of their heads, trudging along toward Uvira, either to sell their goods in the market-place or to take them to the wharf for shipment south and east.

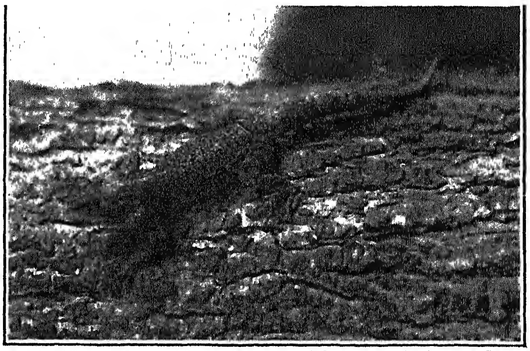
Gradually the road twisted and turned as we climbed to higher levels. Just after dawn we overtook another camion which had stalled, and our chauffeur spent nearly an hour fixing its carbureter, while we walked up and down on the high plateau to keep warm. The sun meanwhile came up in all its splendor, revealing crystalline mountains on both sides of us and the lake to the south. On this plateau the flat-topped acacias of East Africa were in evidence, amid large fields of stubble. The ground was made up of thick alluvial deposits of pebbles and coarse grit, brought down long ago from the mountains and distributed over this broad valley by the Ruzizi River and its tributaries, which have now worked themselves down to deeper levels. On the ground in the stubbly field I found many scattered rings of cuticle about the size of wedding rings. These puzzled me at first, but soon I found that they were segments from the cylindrical, many-jointed body of a large milliped. These beasts are greatly dreaded by both whites and

blacks but are entirely innocuous. Many quaint old men and women passed us while we waited, plodding along with their burdens. The men often carry spears with long slender iron tips, like those of the Masai lion-hunters; they walk erect and carry their loads on top of their heads. The old women carry enormous loads of cotton or other products on their backs, leaning far forward and supporting themselves with a stick. They carry their wealth on their ankles in the form of copper or iron wire anklets. One poor old beldame with deep wrinkles all over her face and purse-like breasts hanging down to her waist had enough of these iron wire anklets on her to tire an elephant.

Resuming our way northward we passed on our left many crystalline mountains, whose contours resembled those around Uvira. We stopped for breakfast at about nine o'clock at the small inn at Luvunghi. It was a brick building in the Arabized African style with arched porches and inner court. The circular thatched straw huts of the natives are surrounded by a flimsy stockade of Euphorbias; tiny gecko lizards run up and down these prickly thoroughfares. In the road a native sits basking in the sun and tinkling his "box-piano" (lukimbe). This instrument consists primarily of a graduated row of iron strips fastened on a resonating box hollowed out of a block of wood by means of a red-hot iron. Shells or small coins are loosely attached to the iron strips and rest on the box, producing a rattling and buzzing sound that is dear to the native ear. Rapid arpeggio movements are executed as the fingers are swept along the lower ends of the metal rods. Complicated rhythms are woven into the arpeggios, and this instrument affords a convenient medium for the expression of "everyboy's" native talent. Two vultures are soaring above us with all the ease and nonchalance for which they are famous.

This place is near the middle of the broad valley, south of the pass through the mountains. Antelopes and elephants are said to be common near here. Some distance beyond Luvunghi we forded the Ruzizi River at a point where elephants frequently came to drink.

After we passed this ford we began to wind our way up into the mountains and our spirits rose steadily with the altitude. Immediately below us the river appeared as a silvery path, meandering over the broad plain; further up the river we could see with our glasses the rapids



Photograph by author.

AGAMID LIZARD.

where it struggled over the blocks which it had itself brought down from the mountains, while far to the north was the deep notch by which it had eaten its way through the mountain barrier as it worked its way southward from Lake Kivu. At this time we were still well below the level of the summits of the ancient crystalline mountains which we had been passing on the way north, and as the road wound upward we were rising from lower to higher levels of the inconceivably ancient foundations of the continent. Evidently we were in a region where there had recently been an immense upthrust, for the process of erosion had not had time to soften the incredibly steep and jagged contours.

Our exhilaration amidst this tremendous evidence of earth history was by no means checked by the dizzy turns the

road was making, often on narrow ledges from which one could gaze down plunging declivities that converged toward the shadowy abyss below. One false turn of the wheel by our black chauffeur and we should catapult through the flimsy wall and do a dazzling series of somersaults to some sudden stopping-place on the way down. But our black was doubtless well used to the giddy contortions and instantaneous shifts of the native dance and in this dance of the camion he and the camion were one. After we came up to a comparatively smooth stretch he lit a cigarette with all the nonchalance of an English speed king.

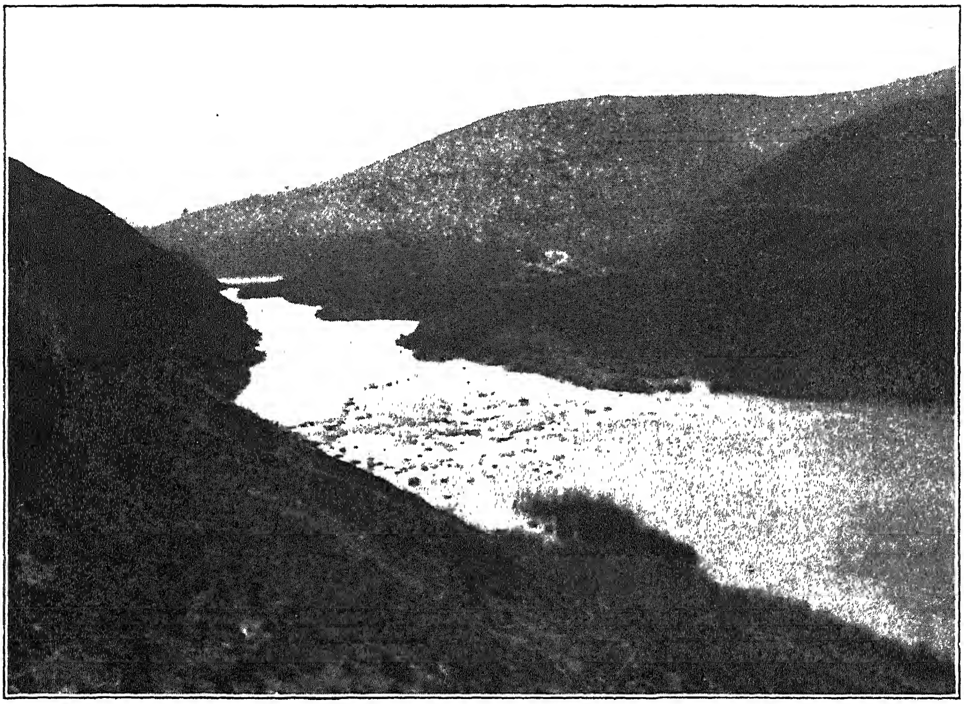
Then came a very long pull upgrade, during which we passed hundreds and hundreds of blacks working on the road. Each one was slowly carrying a tiny basketful of earth or a couple of rocks on his head, but the cumulative labors of these human ants had built this more than Roman highway through the mountains. How tantalizing it was to whirl past this inspiring panorama of human faces, each one with its unique individuality, and to be allowed to snatch only a fleeting glimpse of them.

By and by we came to another camion which had butted its face into the rock of ages without visible damage to the rock. This excited the professional interest of our black jehu, as it gave opportunity for *un gros palaver*.

Accordingly Dr. Engle and I had a chance to take our cameras and walk up to the next protruding tower, which commanded a superb view of the winding river beneath and of the far more precipitous mountains to the north. Apparently we were still below the summit of the old crystalline Archean formations, but there to the north of us we were confronted by threatening outposts of once molten rock, which had burst upward from some vast reservoir below. When this had happened the foundations of the continent had been shaken and

Photograph by E. T. Engle.

EXPEDITION TRUCK UNDER REPAIRS, ON PLATEAU NORTH OF LAKE TANGANYIKA



Photograph by H. C. Raven.

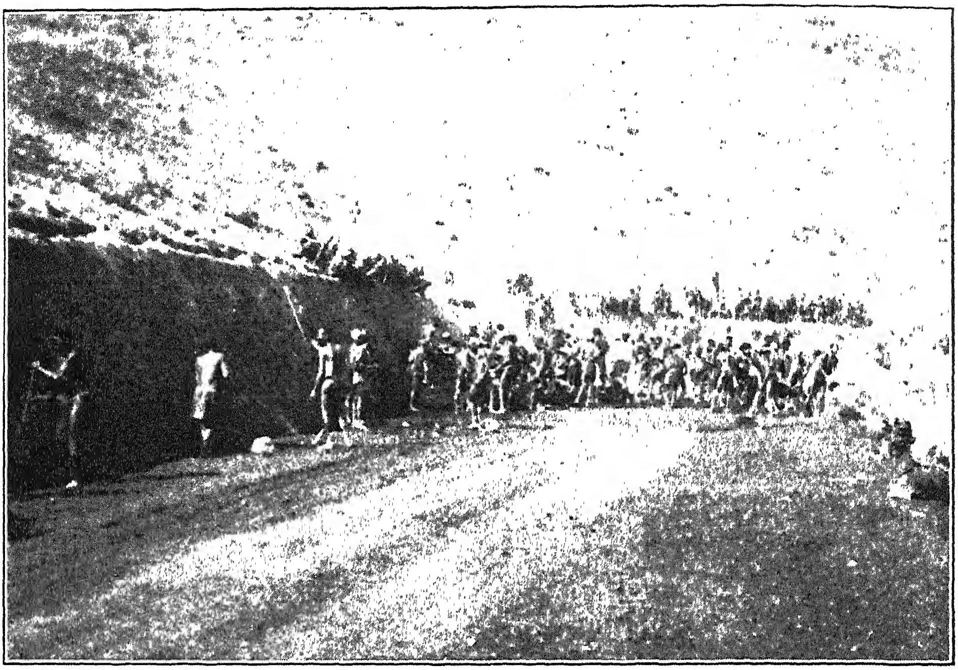
RUZIZI RIVER, SOUTH OF LAKE KIVU.

shattered, permitting enormous earth blocks to settle and pushing others up to precipitous heights. Had this great disturbance been at the time of the formation of the great rift valley or was it of later date, like the very recent volcanic outpourings north of Lake Kivu? Was it this disturbance which had blocked the southern exit of the old Kivu rift valley and thus caused the gradual filling up of the valley by the lake? And then had the Ruzizi River, starting from the overflow of the lake, gradually worked its way south and then dug down until it poured the overflow from Lake Kivu into Lake Tanganyika?[6]

These reflections were interrupted, however, by the arrival of our camion, and Dr. Engle and I regretfully turned our backs on the marvellous scene. Then we began to climb to still greater heights, up over a stupendous gray conical mountain that seemed to be of very recent volcanic origin.

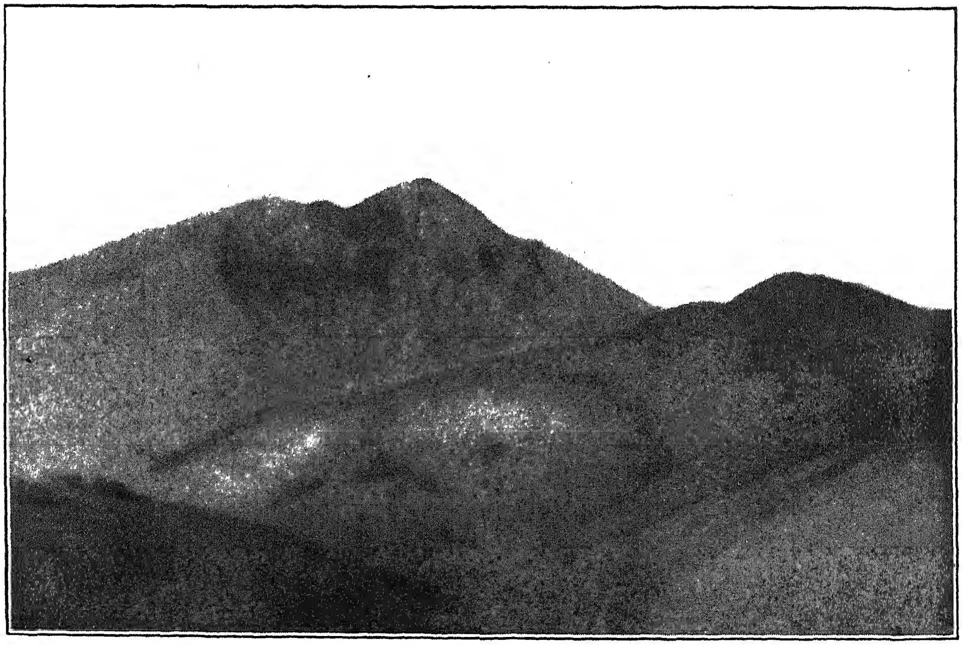
At intervals as we wound around the spiral path, a waiting native would sound a horn, beat a can or hoist an old petrol tin on a high hill, as a signal that the

[6] According to the Encyclopaedia Britannica (14th Ed., 1929, article on Tanganyika), the northern continuation of the Tanganyika rift valley is "suddenly interrupted by a line of young eruptive ridges which dam back the waters of Lake Kivu but have recently been cut through (in about the year 1906) by the outlet of that Lake, the Russisi, which enters Tanganyika by several mouths at its northern end. The flat plain traversed by the lower Russisi was evidently once a portion of the lake floor." According to Dr. Bailey Willis ("Living Africa," p. 121) also: "The Ruzizi drops twenty-six hundred feet from Lake Kivu to Tanganyika, practically all of the fall being in the upper half of its course. Considered as a river, the Ruzizi is but an infant. Not long ago Lake Kivu (or rather the valley it fills) drained northward to the Nile. But volcanoes arose along its course, their lava flows laid a dam across the valley, and it became a lake basin. In a few decades the waters rose to a low pass at the southern end, flowed out there, and produced the Ruzizi river. Its deep gorge is a fine example of youth."



Photograph by E. T. Engle.

ROAD BUILDERS ON THE ROAD TO LAKE KIVU.



Photograph by H. C. Raven.

MOUNTAIN SOUTH OF LAKE KIVU.

road was clear. One could not help wondering what would happen if one of these black traffic cops made a mistake and allowed a descending camion to meet us on the one-way track. But the opportunity of making an exceptionally loud noise by beating the signal-can was too good a one for a native to miss.

On some of these heights, which were almost bare of vegetation, one could look to the north and see the mountains around the southern end of Lake Kivu, wave after wave, as if the earth had liquefied under some stupendous impact. More probably it seemed, the wave-like appearance was due to erosion, by the present drainage system, of an old mountainous district that had been reduced, by an earlier cycle of erosion, to a peneplain or generally flat level.

In this region, which has been subjected to such enormous disturbances, one may be passing at a certain time over a huge block that belongs to the later or volcanic invasion, and a little later, although then further to the north, one may be passing over a block of the far older "crystalline" series belonging to the south; but as one passes beyond the zone of maximum disturbance, the outliers of the older formation become scarcer and one is at last fairly within the zone of the later formation. Thus, as we approached Lake Kivu, the yellowish gneiss-like rocks of the Uvira district became rare, the gray material that we had just passed diminished and we came into the zone of the dark-red soil of the Kivu region.

About twelve o'clock that morning we were winding up and down at high levels along the upper valley of the Ruzizi, passing mountains with boldly serrate and irregular contours which graded southward from the wave-like form, of which we later saw so many around the lake, into the bold jagged cones of gray volcanic material mentioned above. Then we came to hills in which the underlying country rock lies beneath a thick mantle of red soil, which may be the product of the disintegration of the crystalline rocks. After winding down past many bare red hills dotted with long-horned cattle, banana plantations and native huts, we sloped upward a few moments, suddenly drove out on to the long promontory upon which Costermansville (Bukavu) is perched and stopped in full view of the narrow southwestern end of Lake Kivu.

THE APPROACH TO THE ABSOLUTE ZERO OF TEMPERATURE[1]

By Dr. F. SIMON

CLARENDON LABORATORY, OXFORD UNIVERSITY: FORMERLY PROFESSOR OF PHYSICAL CHEMISTRY AT BRESLAU

SPEAKING in this building, with all its associations with low temperatures, a long introduction would be superfluous, but I would like to remind you of some data. In Fig. 1 a temperature scale is given in degrees Centigrade, and you see some important fixed points marked on it.

Now is this scale infinite at both ends or not? We know that heat consists in the unordered motion of the smallest particles, the atoms or the molecules, and the intensity of this irregular motion rises with increasing temperature (in an ideal gas it is directly proportional to it). So it is evident that there will be no limit to high temperatures, as there is none to the intensity of the motion, but of course, there will be a lower limit to the temperature scale, at the point where the thermal motion stops altogether. This point is therefore with justification called the absolute zero. Though it has not been reached in experiment, and as we will see later on, it is by principle impossible to reach it absolutely, its position can be given with great accuracy, and it is found to lie at −273.1° C. A rational temperature scale has, therefore, to begin at this point. In this scale, the Kelvin scale, the absolute zero of temperature is given by the number zero, and any other temperature by adding 273.1° to the number of degrees Centigrade. On the right hand side of Fig. 1 the temperatures are indicated in degrees Kelvin, and you see that the boiling point of the most volatile gas, helium, lies about 4° from the absolute zero. In Fig. 2 you see the liquid helium range given in more detail. By reducing the pressure over the liquid helium, one can easily get down to about 1°. By improving the isolation, and using a huge pump, Keesom succeeded in reaching 0.7°, which was the lowest temperature obtained until a few years ago.

I will begin by showing two experiments. The first is the production of a high temperature. It is a very simple experiment that you have all done yourselves. I need only switch on an electric lamp. By varying the current I get temperatures up to 2,500°.

In the second experiment I will generate a very low temperature, and that is much more complicated. While I could certainly perform the first experiment without any help, the second would be impossible without the kind help of Mr. Green, Dr. Kürti, Dr. London and the staff of the Clarendon Laboratory, who have all helped in its preparation. We will now liquefy helium, making use of a principle about which I will say something later. Now I should like to point out that we start at a temperature obtained with solid hydrogen (about 12°), that within the apparatus there is helium compressed to about 100 atmospheres at this temperature, and that the helium will be expanded into a balloon, where we will store it. During the expansion the helium will liquefy and reach its boiling temperature, 4.2°. As the helium is enclosed in a metal vessel, I will not be able to show it to you, but even if I could, it would not look a bit colder than

[1] Presented at the Royal Institution of Great Britain at one of its weekly evening meetings, in February, 1935.

liquid air. This simplified gas thermometer gives you a much better measure for the temperature. You saw that it pointed first to 12°, then, as the helium was expanded and this balloon filled, the temperature fell to about 4°. I can also show you another proof that we have reached the temperature region of liquid helium.

You have all heard of supraconductivity. This is the name given to the phenomenon discovered by Kamerlingh Onnes, that at certain temperatures some metals lose their electrical resistance altogether. The temperatures at which this happens are very low, they all lie below 10°. In a normal substance a current once induced would disappear very quickly, as its energy would be absorbed within about 1/1,000 of a second by its resistance. In the case of a supraconductor, however, there is no resistance, so that the current goes on flowing indefinitely.

In this lecture room, Professor McLennan[2] showed you this phenomenon of a persistent current in a lead ring, which was brought from Leiden immersed in liquid helium, so I need not speak about it in detail now. For the moment we will only use it to show that we really have the temperature of liquid helium. For this purpose a lead ring is fixed within the apparatus. Lead becomes supraconductive at about 7° so that now at 4° it is already in the supraconducting state. We will now induce a current within this ring.[3]

Before the current was induced a magnetic needle was not affected. Now you see that when I hold it a little above the ring it points with its N pole towards it. This indicates that there is a S pole of the magnetic dipole corresponding to the persistent current. Bringing it below the ring, it naturally changes its direction.

I can show you the existence of this current in yet another way, I have here a small coil connected with a galvanometer. When I bring it up to the apparatus, you see a ballistic deflection of the galvanometer. This is due to the cutting of the magnetic lines of force originating in the persistent current, and the magnitude of this ballistic deflection is a measure of the intensity of the current. So we have here a quantitative measure

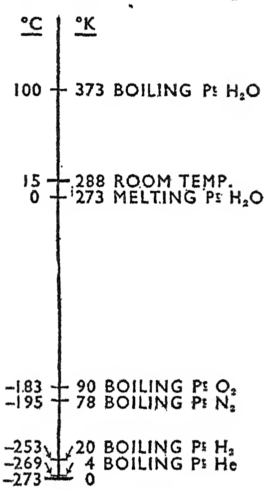


FIG. 1

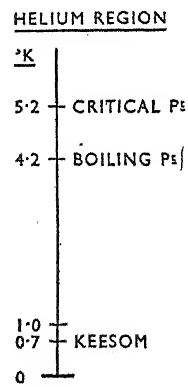


FIG. 2

for the current, and we will verify at the end of the lecture that it is steady.

You see the great difference in outlay for the two experiments. For generating 2,500° you have only to connect an electric lamp to the mains; for generating $-270°$ you have this decidedly complicated apparatus—and yet this is certainly the most simple one in existence. And we have not yet even taken into account that in the second experiment we did not start at room temperature, but at $-260°$. This temperature was obtained by hydrogen which we liquefied in the plant in the Clarendon Laboratory in Oxford, and the liquid nitrogen neces-

[2] *Proc. Roy. Inst.*, Vol. XXVII, p. 446, 1932.

[3] This was performed by switching on a magnetic field, higher than the threshold value of lead at this temperature, so, with the field on, no persistent current flowed; reducing the field, a current is induced, which now persists as the substance is in the field zero.

sary for the hydrogen liquefaction was generated in yet another plant. For the first experiment, on the other hand, I could get the whole plant in my hand by taking a torchlight.

Now what makes this big difference? Heat is due to the irregular motion of the smallest particles. So to heat a substance means to increase its energy, but still more to increase the internal disorder of its particles. To cool down a substance means to diminish its energy, but still more to increase the internal order of its particles. For example, a gas is in a very big state of disorder, the atoms flying in all directions about the space according to their kinetic energy, which is proportional to the temperature. Cooling it down, it will first liquefy, and a liquid is already a much more ordered system than a gas. Cooling it still further, it will solidify; now all the mean positions of the particles are given by a crystal lattice, and the system is in a state of nearly perfect order, only the thermal vibrations of the atoms around their mean positions being still a source of some disorder. Cooling down still further, even this disorder vanishes more and more.

So cooling a substance means bringing it into a state of order, and it is always much easier to make disorder than to establish order. Although you are certainly very familiar with this fact, I will illustrate it by an example. On this tray I have arranged these black and white balls in order. It is very easy now to establish a disorder by shaking the tray, but it is impossible to establish any sort of order again by shaking, or to speak more precisely, the probability of succeeding is extremely small. Of course, I can establish an order by selecting the balls with my hands, but in the case of a system consisting of atoms, this is obviously impracticable, and by principle impossible too. We have only macroscopic means at our disposal. This difficulty of creating order is just what makes the big difference. And this is why, even 10,000 years ago, men were able to generate very high temperatures —sufficient for melting metals—but the low temperature technique is of a quite recent date. Even the ice cream industry is fairly new, though the temperatures involved are not very much below room temperature.

To generate heat one must, of course, have energy at one's disposal, but to transform this energy into the disordered form of heat energy presents no difficulty at all. We saw this in the electric lamp, but one can do it in a great many other ways; for instance, in a candle it is a chemical energy we transform into heat energy, in the brakes of a car it is a mechanical one.

If our example with the balls were absolutely analogous, it would be impossible to generate a low temperature at all, but luckily it is not so, because, unlike our analogy where the order depends only on one variable, in a real physical system it depends on many more. The most important quantity it still depends upon is the volume. Taking the probability of finding an atom within a certain region as a measure for the state of disorder respective to the positions in space, it is quite evident that this probability decreases on enlarging the space the atom has at its disposal. So in a diluted gas we have a great disorder; if it is compressed to a small space, its order is increased.

Now thermodynamics has given us a quantitative measure for this state of order of which we have to speak so much now, since it is necessary for understanding things later on. This measure is called the entropy. I will not trouble you with this quantity, as I know it is not a very popular one. I only want to remind you that it is a measure for the state of order, and that there is a law, namely, the second law of thermodynam-

ics, which tells us that within a closed system during any change the entropy can only increase, or at the best by making a reversible change (that means avoiding unnecessary disorder) it can remain the same. Speaking in our terms now, this second law means that in a closed system the state of order can only decrease or at the best remain constant.

Let us see now what this has to do with generating low temperatures. We will take a cylinder with a piston, containing a gas, the whole system being perfectly isolated from its surroundings. The state of order in this system consists of two parts, one depending on the temperature and the other on the volume. Compressing the gas, we increase the state of order corresponding to the volume. As the whole state of order must remain the same, the disorder due to the thermal motion has to increase, that means the temperature rises, and you all know that in compressing a gas it heats up, this heat being called the compression heat.

Bringing this system into thermal contact with its surroundings, it will cool down to the initial temperature, and so its disorder becomes smaller. But of course, that does not contradict the law I spoke of before, because heat is transmitted to the surroundings, so increasing the disorder of the particles there.

Now we will isolate the system again and pull the piston out. The part of the disorder due to the volume increases again. The whole state of order must remain constant, so the part of the disorder due to the temperature must fall, and that means the temperature itself falls.

That is a characteristic example, and one of the most important cases of how to generate a low temperature. Generally speaking, whenever one wants to lower the temperature, one must have a system in which the state of order can be changed by some external means. Then in the way described above, one is able to transmit a part of the original disorder in the system to the surroundings, and to cool it down, making the same change of this variable in the opposite direction after having isolated it from the surroundings.

Gases are the prototype of a disordered system, the existence of which is necessary for the procedure of generating low temperatures, and it is relatively easy with them to change this disorder by changing the volume. So practically all procedures for generating low temperatures were worked with gases until recently. Of course, one can make use of them only down to the temperatures at which they liquefy, or more precisely, as long as their vapor pressures have still practicable values. So in practice the generation of low temperatures and the liquefaction of gases have become practically identical conceptions, and every step towards a lower temperature has been marked by the feat of liquefying a gas with a lower boiling point than was previously possible.

I will not speak now of the development of the real procedures performed with gases in order to liquefy them, which, for technical reasons, have to be much more complicated than the example I gave you. I need only remind you of the names of Faraday, Cailletet, Pictet, Olzewski, Linde, Hampson, Dewar, Claude and Kamerlingh Onnes. You know that it is now relatively easy to get down to the temperature of liquid air, as the liquefaction of air has become important for industrial technique. But I want to mention that to cool by one calorie, at even such a relatively high temperature as that of liquid air, is already 500 times as expensive as to heat by a calorie above room temperature, for instance, by burning benzene. But at lower temperatures the difficulties increase enormously, so that the use of liquid hydrogen has been restricted to a few laboratories, and that of liquid

helium to still fewer big specialized laboratories.

In recent years the study of the properties of matter at very low temperatures has become increasingly important, and so, of course, one has sought for ways of simplifying the low temperature technique. We have in the last few years developed a comparatively simple method for liquefying helium, which I have shown you already, and now I should like to say a few words about it. The procedure of expanding a gas in a cylinder, in the way already described,

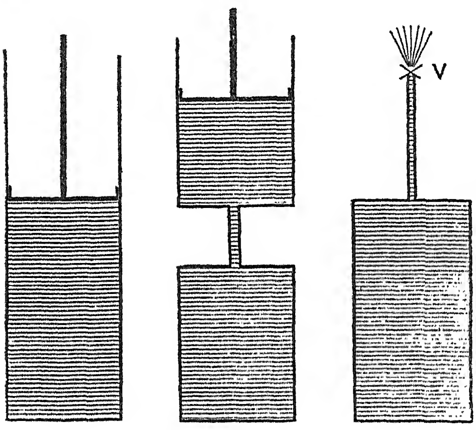


FIG. 3. PRINCIPLE OF THE EXPANSION METHOD.

is very simple. But at very low temperatures it is difficult to realize technically a cylinder and a piston.

But one can overcome this difficulty in a very simple way, which I will now explain. In Fig. 3 A we have a gas enclosed in a cylinder with a piston. Pulling out the piston, the gas will cool down. In Fig. 3 B you see the cylinder divided into two parts connected by a tube. Pulling out the piston now, the gas will cool everywhere, because this cooling is an homogeneous procedure. Let us cool now only the lower part to the low initial temperature at where we start (for example, to the temperature of liquid hydrogen if we want to liquefy helium); leave the upper part at room temperature, and pull out the piston again. Then the gas will cool down within the lower part, the same as if the upper part were at the low initial temperature too. The atoms in the lower part do not know whether the upper part is hot or cold and the atoms do not know either if there is a cylinder and piston outside. We get the same effect if I simply let it out by a valve, as in Fig. 3 C. I want to emphasize that the cooling arises within the cylinder, and not at the valve, as in the Linde process. The procedure described above has nothing to do with the Linde process, but it has more resemblance to the Cailletet method. You remember, perhaps, that he let a gas expand in a glass capillary tube, and with some of the so-called permanent gases, he could then see a little dust of liquid drops, indicating that for some fraction of a second the temperature had fallen considerably.

Now starting at high temperatures, the cooling effects obtained in this way are very small. The chief reason for this is that a container for high pressures has, at room temperatures, a heat content that is always big compared with that of the gas. Starting at low temperatures, however, the situation changes absolutely. Firstly, one gets a much bigger amount of gas into the container at a given external pressure, according to the gas laws, and secondly, the specific heats of all solid bodies drop with temperature, disappearing on approaching absolute zero. So for instance, at a temperature of about 12°, 1 cu. cm. of helium gas compressed to 100 atmospheres has the same heat capacity as 1 kilogram of copper. This means we can neglect the heat capacity of the walls altogether, and we have the advantage of working with mathematical walls. Thus the efficiency of the procedure as I described it to you becomes very high, and working with suitable dimensions and a good isolation, it is easy to keep the low temperatures too. For instance, under the conditions

realized in this apparatus, about 60 per cent. of the volume originally filled with the compressed helium remains filled with the liquid phase, and in the apparatus we generally use we can raise this efficiency still much higher.

In this way one could liquefy any quantity of helium. But as the specific heats at low temperatures are so very small, only tiny amounts of liquid helium are really necessary for cooling down the apparatus and making measurements for a number of hours, if the apparatus is designed in a suitable way. For example, in this apparatus we have liquefied about 50 cu. cm., which is sufficient to cool down the whole system and to work for about five hours.

In Fig. 4 you see a rough plan of the apparatus. Outside is the vessel D with liquid hydrogen; inside, the space S that is evacuated. Within this you see the container C that is first filled with compressed helium, and after the expansion with liquid helium. Attached to this container is a gas thermometer G, the readings of which you saw before.

To cool the apparatus down further, one could reduce the pressure over the liquid helium; the temperature must then fall till it corresponds with the vapor pressure of the helium. For purely technical reasons we do not do this, but we have a second vessel E that we can fill with liquid helium by letting helium gas through the tube T. Then it condenses in the tube T where it is in contact with C, and drops down into the vessel. By pumping through T now, we reduce the vapor pressure, and therefore the temperature falls. This vessel and the surrounding Dewar vessel are of this peculiar shape because we will afterwards apply magnetic fields to some substance situated in the vessel, and of course, one can generate strong magnetic fields over a small distance more easily than over a big one. Now we will pump off the helium in this vessel, in order to reduce the temperature here, and the temperature will fall below 2° within a short time.

Before we consider the methods of generating still lower temperatures, I want to refer briefly to the measurements of these temperatures. You know that in general one measures temperature by the pressure of a diluted gas, using it as a substitute for an ideal gas. But at the lower limit of the liquid helium range the only existing gas, the helium, is stable only at a pressure so small that it is of no use for a thermometer. In this region one can use another phenomenon for measuring the temperature.

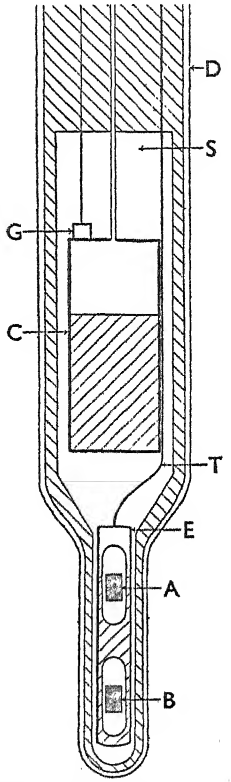


FIG. 4. SIMPLIFIED DIAGRAM OF THE APPARATUS.

The thermometer that I want to speak of now is a magnetic one, and it depends on the fact that paramagnetic susceptibility is a function of temperature. In a paramagnetic substance there exist little

elementary magnets, which we will assume for the moment to be perfectly free to point in every direction in space. The thermal agitation has the effect of making the directions of these elementary magnets have a random distribution. Applying a magnetic field, it will try to turn them in its direction; on the other hand, the thermal agitation tries to establish a disorder with respect to the direction of the dipoles. There will be a compromise of these two effects, and it is evident that the lower the temperature, that means the lower the thermal agitation, the more magnetized the substance will become. Calculating this numerically, one finds that in such a substance the magnetic susceptibility would be proportional to $1/T$. That is the famous Curie Law, which was derived primarily for paramagnetic gases, because there the single elementary magnets connected with the atoms or molecules are certainly perfectly free. At first sight one might think that within a solid body the condition of free elementary magnets could not be realized. But experiments, made chiefly in the Leiden Laboratory, have shown that there are some paramagnetic salts which follow Curie's law down to the helium temperatures with great accuracy, and this means that the elementary magnets within them have a very high degree of mobility. The salts concerned are especially those of the rare earth and iron groups. I can not go into a theoretical explanation of this behavior, but I want to mention that it is in accordance with our theoretical ideas.

So it is easy to construct a thermometer with such a paramagnetic substance, using its susceptibility as a measure for the temperature. And it is evident that a thermometer of this kind becomes very sensitive at low temperatures. For example, between 4° and 1° the susceptibility changes in the proportion 1 : 4. We have a thermometer of this kind in our apparatus. We measure the susceptibility by bringing a system of two coils around the place where, inside the apparatus, the salt is situated, and sending an alternating current through the primary coil; the induced e.m.f. in the secondary depends on the susceptibility of the salt which is fixed within these coils. This induced e.m.f. is amplified in a little set (which the Cambridge Instrument Company have very kindly lent me for the demonstration), then it is rectified and sent to a galvanometer that shows the deflections on this scale. Of course, the system is compensated in such a way that the deflection zero corresponds to a susceptibility zero within the coils. Thus the deflections on the scale are a direct measure of the susceptibility, and as this changes with $1/T$, the deflections are proportional to $1/T$. At the moment the thermometer is showing about 2°.

Now we can continue considering how to approach nearer to the absolute zero. As I have mentioned already the lowest temperature reached by reducing the vapor pressure of liquid helium is 0.7°. At this point the vapor pressure is so small that it is in practice impossible to proceed further. A gas with a still lower boiling point does not exist. Very probably the new helium isotope, helium 3, discovered in the Cavendish Laboratory, will be more suitable for reaching low temperatures, if it can ever be obtained in sufficient quantities, but there will be no difference in the order of magnitude.

You may be wondering why we should bother to get still nearer to absolute zero, as it seems so difficult now to get down any further. What can still happen in this small region? To answer this question, we have to ask another. When can one predict that something will happen in a certain temperature region?

Let us assume that the phenomenon we are interested in is connected with an energy change of a certain quantity.

Then the thermal agitation will have an influence on it when it itself reaches this order of magnitude. So we see that from this point of view, there is no sense in speaking of an absolutely high or an absolutely low temperature; it is always necessary to compare it with the phenomenon in which we are interested. For instance, room temperature is a very low temperature if we look for the evaporation of diamond, because its heat of evaporation is very high (*i.e.*, only at high temperatures is the thermal agitation big enough to push a carbon atom out of the crystal). But room temperature is a very high temperature if we look for the evaporation of hydrogen, as its heat of evaporation is very small. So the question is, are there any phenomena connected with very small energy changes, that means, phenomena which will still happen at very low temperatures?

If the atoms were only points possessing attractive or repulsive forces, then certainly nothing much of interest would happen within the new region. The thermal agitation would become smaller, but this would not give rise to any new phenomena. However, we know that although in the kinetic theory it was for a long time sufficient to treat the atoms as points with attractive and repulsive forces, yet this is certainly not a complete picture. We know that the atoms are built up from nuclei and electrons. In general one is accustomed to find the effects of this complexity of the atoms only in gases at high temperatures, as most of them are connected with big changes of energy. It is true that at normal temperatures the effects originating in the complexity of the structure of the atom are not very striking in a solid body, but certainly some do exist. For instance, we spoke just now of the magnetic properties of some salts. If the atoms were only points with forces, they could not show any magnetic properties. These are due to the motion or the spin of the electrons, and here we have one effect of the structure of the atom. We have seen already that this effect becomes more and more striking as the temperature is lowered. We have also considered another phenomenon that would not have been possible if the atoms had only been points. A system of points could not show metallic conductivity. That is due to electrons split off the atoms within the metal, and we have seen that with these electrons, something happens only at very low temperatures, namely supraconductivity. Here some change takes place connected with an energy difference of such an order of magnitude that it becomes equal to the thermal agitation only at very low temperatures; and I may mention that at present it is not known what exactly is happening in the metal. It would be very important to see whether, at still lower temperatures, all metals become supraconductive, that is, whether it is a general property of all metals.

So we see that it is of interest to extend our temperature range to lower temperatures, and we will find later on that there are still more phenomena that can be expected to take place below 1°.

But in order to go lower, how can we proceed? As we discussed before, to get a low temperature, one must have a system at one's disposal which is still in a big state of disorder, and one must be able to change this disorder by changing an external variable. At these temperatures we no longer have gases. What other disordered systems still exist? Well, we have just seen one, namely, the paramagnetic salt which still follows Curie's law, and about ten years ago Debye and Giauque proposed using this for the generation of still much lower temperatures.

To understand the principle, look at Fig. 5, which represents a paramagnetic salt. The circles represent the atoms

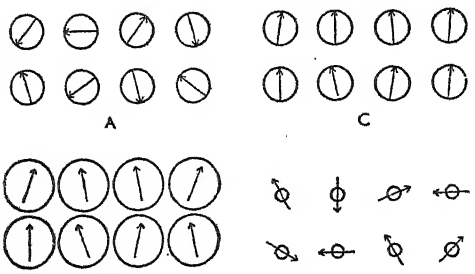


FIG. 5. PRINCIPLE OF THE MAGNETIC COOLING METHOD.

arranged in a crystal lattice, and the little arrows represent the magnetic moments attached to every atom. Without a field (Fig. 5 A) there exists, as we saw before, a random distribution of the directions of the dipoles, so the disorder in this system consists of two parts; one is due to the distribution of the directions of the dipoles and the other to the thermal motion of the atoms. (The diameters of these circles indicate the magnitudes of the vibrations and give also in this way a measure for the disorder to the thermal vibrations.) Applying the field now (Fig. 5 B) it will try to order the directions of the dipoles. Making it adiabatic, that is, having the system isolated thermally from its surroundings, the whole state of order should remain constant, which means that the disorder due to the thermal movement must increase, in other words, the temperature rises (corresponding to the compression of the gas in our former example). Making heat contact with the surroundings the system cools down to the initial temperature, so that now the state of order has increased (Fig. 5 C). Now, isolating the substance from the surroundings, and taking the field away, the dipoles try to distribute their directions at random again, the disorder due to this increases, but as the whole state of order must be constant, the temperature must fall (Fig. 5 D). (Corresponding exactly to the adiabatic expansion of the gas.)

Within the last few years this method has been used experimentally, and at nearly the same time Giauque in California, de Haas in Leiden and Dr. Kürti and I began to work with it. We developed the technique so that it is now fairly easy to work with this procedure, and we can show you an experiment with it here in this room.

We will look once again at Fig. 4. There you see within the lower vessel two different paramagnetic salts A and B, so that we can do two different experiments. To carry out the cooling by this method, one has to have the substance in thermal contact with the surroundings when the field is switched on, and isolated when the field is switched off. We do this automatically by suspending the substance in a little glass tube closed at both ends and filled with about 1 cm helium at room temperature. This gas makes a heat contact with the surrounding helium bath during magnetization. Switching the field off the substance cools quickly, and the helium gas has to condense on it, as the vapor pressure falls rapidly with falling temperature. Choosing the right dimensions and vacuum conditions, one can in this way use the cooling substance itself as a pump.

Now we will begin with an experiment[4] taking first the upper substance, A, manganese ammonium sulfate. We bring the magnet into position and switch on a field of about 10,000 gauss. We have to wait now for about a minute until the heat of magnetization is carried away. Next we remove the magnet and bring the coils for the temperature measurement into position. The substance has cooled down, the thermometer points to about 0.25°. At the same time you notice that the temperature keeps quite steady.

[4] During the lecture a wire of the thermometer circuit broke, so that the experiment could not be performed. However, it was shown to a large number of the audience three quarters of an hour later when the trouble had been repaired.

We will now make another experiment with the lower substance, B, iron ammonium alum, and the same field. We have now reached 0.1°, and you see that again there is hardly any change of temperature.

Now we will look at Table I, which gives the vapor pressures of helium at different temperatures. Although they have not been measured experimentally, these figures are very accurate, since we have all the necessary data at our disposal for calculating the vapor pressures according to the second law of thermodynamics. You see that at 0.1° the vapor pressure is 10^{-31}, and at 0.25° it would be about 10^{-12}, so that there is practically no gas which could transmit heat from the surroundings. At 0.5°, however, we have a vapor pressure 10^{-5}, which is no longer negligible. In this case the substance would warm up much more quickly, and so we have the paradox that it is much easier to keep a temperature below, let us say 0.3°, than one above this temperature.[5]

TABLE I

VAPOR PRESSURES OF HELIUM

T	p (mm)
1.0	1.5×10^{-1}
0.7	3.2×10^{-3}
0.5	2.5×10^{-5}
0.3	7×10^{-10}
0.2	3×10^{-15}
0.1	3×10^{-31}
0.05	4×10^{-62}
0.03	6×10^{-103}

At these very low temperatures one can get any isolation one likes, for instance, at 0.03° we have a vapor pressure of 10^{-102}. The surroundings of the substance are at a temperature of about 1°, where the radiation is certainly negligible, and one can make the suspension so that very little heat is conducted to the substance. Thus we have really no difficulty in keeping temperatures as long as we like, even working with very small amounts of substances.

You saw that using different paramagnetic salts, we reached different final temperatures, which means that all substances are not equally good for this method. Of the many substances we investigated, iron ammonium alum was found the most suitable, and with it we have got down to about 0.04°, using a field of 14,000 gauss. De Haas reached 0.015° with this procedure, using potassium chromium alum, and having the huge magnet of the Leiden Laboratory at his disposal.

I may remind you that the temperature of a material body in the interstellar space can not fall below 2° or 3° K., as it always has to be in equilibrium with the stellar radiation. So you see that in this case we can realize in the laboratory a lower temperature than we can find in nature, and we can surpass the conditions found in nature in still another way. We will look once again at the table of the vapor pressures of helium, the most volatile gas existing. In the interstellar space there is a vacuum of about 10^{-22} cm. Hg. You see that we have already reached this pressure in a space surrounded by a body at a temperature of about 0.15°, even when it is filled with the most volatile gas. At 0.03° the pressure would be so small that in the whole galaxy we would not find one single atom in equilibrium with it. So, in the directions of low density and low temperature, we can surpass in the laboratory the conditions found in nature, whereas, in the opposite direction it is extremely unlikely that we will ever reach the high temperatures and big densities to be found in the stars.

There is not much point in generating low temperatures simply for the fun of

[5] Of course, one could establish a vacuum by means of pumps, but at low temperatures the helium is absorbed in big amounts on the walls, and it would take a very long time to obtain a sufficiently high vacuum.

playing among the low figures. How can one make investigations on substances other than the paramagnetic salts? The most simple way is to press the paramagnetic salt and the substance to be investigated together, so that they form a solid pill. In cooling down the salt, the substance cools with it. In this way we examined a lot of metals to see whether they became supraconducting or not, and three new supraconductors were found in the new region. Some other metals, however, did not become supraconducting down to 0.05°.

At the same time these measurements showed us still another thing. Cooling an additional substance with the paramagnetic salt and seeing how far the temperature is lowered in demagnetizing, compared with the temperature reached in demagnetizing the pure salt, one can measure the specific heat of the additional substance, and see whether anything happens within the new temperature region. If there is any change of energy within the substance that is equal to the thermal agitation in the new region, then it should be seen in these specific heats. And there is a very definite thing that must be expected to happen in this region. As is known from the analysis of the atomic spectra, there is an interaction of the magnetic momenta of the nucleus with that of the electrons, chiefly the valency electron. As a result of this, the ground state of the atom is split up, and the energy difference between the different levels is of such an order of magnitude that the new temperature region is characteristic of it. We have already got some results in this direction, but it would be proceeding too far now to go into details.

You saw that within this new temperature region there really are things that still happen, and it is not only a game with low temperature figures. One can also say that it will be both necessary and interesting to investigate temperatures lower than those yet reached.

What imposed the limit to the temperatures reached above? It should be possible to get down to any temperature if the dipoles in the salt were perfectly free, because then, even as near to absolute zero as one likes, there would be a random distribution of the magnetic dipoles, and we would always still have a means of lowering the temperature. But here the same thing happens as in the case of gases. If we had still a gas at these very low temperatures, we could certainly use it for lowering the temperature, but no more gas exists, because there are forces between the atoms that cause the system to pass over to a state of order—the crystal—and there is no longer any disorder that we could make use of for lowering the temperature. In the paramagnetic salt the same thing happens, only at temperatures about 100 times lower. In them there also exists interaction forces which have the effect of establishing an order within the system without an external magnetic field, and so at these temperatures the paramagnetic salts cease to be of use. These temperatures differ, of course, from substance to substance, and we saw in our experiments that the manganese ammonium sulfate passed over into this state earlier than the iron ammonium alum. Of course, one could get a bit further by using still stronger magnets, but I think the practicable limit has been reached with the dimensions of the Leiden magnet.

A more hopeful way seems to be to work in two stages. That means, first work down to about 0.05°, and then starting at this temperature go still lower with a new procedure, like the cascade for liquefying gases, which was used so much in the past. Of course, to get to appreciably lower temperatures for the lower stage it will be necessary to find a

substance in which these interaction forces, which tend to bring the system into an ordered state, are still smaller than within the substances hitherto used. I have already said that the interaction forces between the nuclear moments and their surroundings are very small, and in the second stage one will have to try to work with a substance that exhibits nuclear paramagnetism.

But even here there are some interaction forces, and so this will only work for a bit of the way to absolute zero. And with all other phenomena that may still happen in the new temperature region, it will certainly be the same. There exists a law, Nernst's Theorem, also called the third law of thermodynamics, which is confirmed by all experiments. It postulates that at absolute zero all substances are in a state of perfect order, or in other words, that the state of lowest energy must be a state of perfect order. And we know now that this means that it will be impossible ever to reach the zero of temperature absolutely. But this does not mean that one can not get below a certain limit, say 1/10,000°. It will be possible to reach any finite temperature, be it as small as you like. But the technique of reaching such a temperature will always be dependent on finding a phenomenon, connected with only a very small energy change, happening within a system. And so you see that this last degree, or as we may say now, the last 1/100° to absolute zero, though absolutely very small, stretches in reality an infinite distance before us. And this infinity is not an empty one, but one that is filled with phenomena worth investigating.

SCIENCE AND MILITARY TECHNIQUE

By ROBERT K. MERTON
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The subjects investigated by science are determined by social, as well as purely scientific, factors.—Military technology has focussed scientific attention upon certain groups of problems.—About ten per cent. of the research conducted by members of the Royal Society in seventeenth-century England was so influenced.

THE foci of scientific interest are determined by social forces as well as by the immanent logic of science. It is only by examining extra-scientific influences that one can fully comprehend the reasons why scientists have applied themselves to one field of investigation rather than to another. For science is a social outgrowth and the direction of scientific research is largely induced by social factors. With the view of tracing such a connection between science and society, I shall indicate the ways in which military exigencies have encouraged the growth of one branch of science, especially in seventeenth-century England.[1]

The seventeenth century in England was one in which war and revolution were rife. Moreover, the dominance of firearms (both muskets and artillery) over side-arms first became marked at this time—swords and pike disappeared almost completely as weapons of importance (except as they were incorporated in the removable bayonet about 1680). Especially notable was the enhanced use of heavy artillery, for in this field occurred a change of scale which raised new technical problems. Ever since the early fourteenth century, cannon, or "firepots," had been used in warfare, but it was not until three centuries later that they played an important rôle in military technique.

[1] Compare the paper by B. Hessen in "Science at the Cross Roads," pp. 151–212. London, 1932.

Leonardo was one of the first to combine military engineering and scientific prowess, as is evidenced by his polygonal fortress, steam cannon, breech-loading cannon, rifled firearms and wheel-lock pistol. Other scientists likewise employed themselves with such matters. Niccolo Tartaglia, in his "Nuova scienza" (1537), dealt with the theory and practice of gunnery. Georg Hartmann invented a scale of calibers which provided a standard for the production of guns and furthered the empirical laws of firing. Galilei, in his "Dialoghi," suggested that (ignoring air resistance) the trajectory of a projectile described a parabola; while Torricelli concerned himself in great detail with the problems of the trajectory, range and fire zone of projectiles. Leibniz, as is evidenced by his posthumously discovered writings, was greatly concerned with various aspects of military problems, such as "military medicine," "military mathematics" and "military mechanics." He also worked on a "new air-pressure gun," as did Otto von Guericke and Denis Papin. Isaac Newton, in his "Principia" (Bk. II, sect. i–iv) attempted to calculate the effect of air-resistance upon the trajectory of a projectile. Johann Bernoulli, who also studied the expansion of gunpowder gases, pointed out Newton's error, with the result that it (Bk. II, Prop. 37) was eliminated in the second edition of the "Principia." Euler continued the theory that the parabola best approximates the actual trajectory of a projectile; a subject dealt with minutely by Maupertuis.

But all this simply indicates that out-

standing scientists have at times been directly concerned with matters of military technique. In order to see the ways in which such practical exigencies aroused research in certain fields of "pure" science, it is necessary to make a detailed study of another sort.

The technical and scientific problems set by the development of artillery in the seventeenth century were briefly these. Interior ballistics is concerned with the formation, temperature and volume of the gases into which the powder charge is converted by combustion, and the work performed by the expansion of these gases upon the gun, carriage and projectile. Formulae for the velocity imparted to a projectile by the gases of given weights of gunpowder and for their reaction upon the gun and carriage must be computed to determine the correct relation of the weight of charge to the projectile's weight and length of bore, the velocity of recoil, and the like.

Not only were such nineteenth century scientists as Gay-Lussac, Chevreul, Graham, Piobert, Cavalli, Mayevski, Otto, Neumann, Noble and Abel concerned with these problems, but also many earlier investigators. Of obvious fundamental importance for interior ballistics is the relation between pressure and volume of gases. That the volume of any gas varies inversely as its pressure was first stated by Boyle in 1662 and verified independently by Mariotte some fourteen years later. Apparently Boyle was not unaware of the relation between his discovery and problems of interior ballistics, for he proposed to the Royal Society "that it might be examined what is really the expansion of gunpowder, when fired."[2] This same problem was investigated in detail by Leeuwenhoek, who, although he resided in Holland, may be considered in the stream of "English science," by virtue of the 375 papers which he sent to the Royal Society, of which he was a member. His experiments in interior ballistics, published in the *Transactions,* aroused sufficient interest to be repeated before the society by Papin.

At one of the early meetings of the society, both Boyle and Lord Brouncker, the latter of whom was especially interested in ballistics, suggested experiments on air-pressure and the expansion of gases. One of the proposed experiments dealt with the inflammation and combustion of a charge of powder—a problem basic to the noted memoirs in interior ballistics by Noble and Abel, read before the Royal Society in 1874 and 1879, respectively.

At one of the earliest meetings of the society "the lord viscount Brouncker was desired to prosecute the experiment of the recoiling of guns, and to bring it in at the next meeting."[3] These experiments were frequently repeated and followed with great interest by the other members of the society.

Exterior ballistics is concerned with the motion of a projectile after it leaves the gun: it treats of the trajectory and the relation between the velocity of a projectile and the resistance of the air. The most notable experiments in exterior ballistics in the last two centuries were those by Robins, Hutton, Didion, Poisson, Helie, Bashforth, Mayevski and Siacci, but these were in turn largely based upon scientific work of the preceding period.

The fact that Galilei introduced his "Discorsi," in which he dealt with the trajectory of a projectile, with an acknowledgment of the assistance rendered him by the Florentine arsenal suggests that he was aware of his work for ballistics. Moreover, as Whewell noted, the practical military applications of the

2 Thomas Birch, "The History of the Royal Society of London," I, p. 455, 4 vols. London, 1756.

3 Birch, *op. cit.*, I, p. 8.

doctrine of projectiles doubtlessly helped to establish the truth of Galilei's views.

The study of the free fall of bodies—so essential to exterior ballistics in its initial stages—was continued by Robert Hooke in his experiments with the fall of "steel" bullets. He followed this investigation with some experiments designed to determine the resistance of air to projectiles. This resistance, he maintained, could be tested by "shooting horizontally from the top of some high tree." Hooke went further and constructed an engine "for determining the force of gunpowder by weight"—an experiment which proved of sufficient interest to be repeated at two subsequent meetings of the society.

Christopher Wren, concerned with the invention of "offensive and defensive engines," was, with Wallis and Huygens, the first to state correctly the motion of bodies in their direct impact. This law, together with the first two laws of motion, affords a basis for an approximation to the trajectory of a projectile.[4] Roger Cotes, Newton's disciple who redacted the second edition of the "Principia," similarly occupied himself in his "Harmonia Mensuarum" with the motion of projectiles.

The problem of the trajectory was attacked by Halley, who demonstrated the utility of Newton's analysis in the "Principia" for this purpose. Cognizant of the economic, as well as technical, advantages to be derived from his mathematico-mechanical formulation of the approximate trajectory of projects, Halley indicated that his "rule may be of good use to all Bombardiers and Gunners, not only that they may use no more Powder than is necessary to cast their Bombs into the place assigned, but that they may shoot with much more certainty."[5]

Sir Robert Moray introduced to the society Prince Rupert's gunpowder, "in strength far exceeding the best English powder," as well as a new gun invented by the prince. Moray likewise suggested a series of experiments in gunnery, which were broadcast in the *Transactions*. These trials aimed to determine the relation between the quantity of powder, caliber of gun and the carrying distance of the shot. Similar experiments were conducted by the sometime Savilian professor of astronomy, John Greaves.

It appears evident that contemporary scientists were interested in problems and investigations which pertained directly to military technology, but, what is perhaps less apparent and more significant, many researches devoted to "pure science" were also related to such problems. For example, the study of the free fall of bodies, which since Galilei occupied such a prominent place in physical research, is necessary, if the trajectory and velocity of a projectile is to be determined. The connection between these problems was made explicit when an experiment was frequently performed before the Royal Society "for finding the velocity of a bullet by means of the instrument for measuring the time of falling bodies."[6]

In an effort to determine the approximate extent to which military techniques and problems have tended to focus the attention of scientists upon certain problems, I have computed the comparative number of inquiries and experiments carried on by the Royal Society which are related, directly and indirectly, to such military needs. By tabulating the number of experiments listed in the minutes of the society during four years in the later seventeenth century and classifying them in terms of the fields to which they pertained, it is possible to secure an approximate comparison of

[4] See the "Principia," "Scholium to Laws of Motion."

[5] *Philosophical Transactions*, 16: 3–20, 1686.

[6] Birch, *op. cit.* I, pp. 461, 474, *passim*.

this kind. Each experiment or inquiry listed in the society's minutes (as published in Birch's History) is counted as one "unit" and classified in the field to which it is most closely allied. The field of military technology was classified in the following fashion.

MILITARY TECHNOLOGY

A. *Directly related research:*
  (1) Study of trajectory and velocity of projectiles.
  (2) Processes of casting and improvement of arms.
  (3) Studies of the relation of the length of gun-barrels to the range of bullets.
  (4) Study of the recoil of guns.
  (5) Experiments with gun-powder.

B. *Indirectly related research:*
  (1) Compression and expansion of gases: relations between volume and pressure in the gun.
  (2) Strength, durability and elasticity of metals: elastic strength of guns.
  (3) Free fall of a body and conjunction of its progressive movement with its free fall: determination of the trajectory of projectiles.
  (4) Movement of bodies through a resistant medium: enables a closer approximation to the trajectory of projectiles as influenced by air resistance.

In the year 1661, the Royal Society pursued 191 separate scientific investigations. Of these, 18 (15 directly related, 3 indirectly related) or 9.4 per cent. were related to military technology. In 1662, of 203 projects, 23 (4 direct, 19 indirect) or 11.3 per cent.; in 1686, of 241 projects, 32 (22 direct, 10 indirect) or 13.3 per cent.; and in 1687, of 171 projects, 14 (8 direct, 6 indirect) or 8.2 per cent. Thus we see that on the average about 10 per cent. of the research carried on by the foremost scientific body in seventeenth-century England was devoted to some aspect of military technique. To an appreciable extent, then, this one extra-scientific factor tended to focus scientific attention upon a given body of scientific problems.

The relations between military demands and the scientific development of the time were primarily of two sorts. The first involved conscious, deliberate efforts of the contemporary scientists directly to solve problems of military technology. This is what is meant by a *direct* relation. The second type is less apparent, for it concerns scientific devotion to problems which, although either imposed or emphasized by military needs, seemed to the scientists as primarily of purely scientific interest. This was called the *indirect* or derivative relation. Concern with the expansion of gases, combustibility of powder and the consequent pressure of the products of combustion, and the durability and resistance of materials may in individual instances involve no consciously felt connection with military technology, although the original impetus for such study may have been considerably enhanced through military requirements. These derivative problems may enter into scientific tradition as problems of purely scientific interest, and yet may have been originally introduced for practical reasons. This is to say that many scientific researches proceed along lines largely independent of social forces once the initial problems have become evident, and in this way, research may progress which is related only in a tenuous and hardly appreciable fashion to military or economic developments. Thus science develops a corpus of investigation which has its origin in strictly scientific, and not grossly utilitarian, considerations. It is these developments (which probably constitute the greater part of science) arising from the relative autonomy of scientific work that seem to have little or no connection with social forces.

A THEATER OF THE SCIENCES

By Dr. IRA M. FREEMAN

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THE steadily increasing interest in scientific matters on the part of the general public is one of the most remarkable social and cultural phenomena of recent years. The wide-eyed wonder at the "mysteries and marvels of science," which was the characteristic reaction of the public a quarter of a century ago, is being replaced by a sober inquisitiveness and serious interest; and thinking individuals are demanding that their curiosity regarding scientific matters be satisfied in a legitimate manner.

It is true that attempts are being made to meet this need. There are press associations and individual newspapers conveying trustworthy and accurate scientific information to their subscribers, but neither scientific journalists nor journalistic scientists have been able to reach any degree of unanimity on methods of presentation,[1] and—with the exception of a small number of reputable writers and press associations—the field is still in the hands of charlatans who, in their innocence, believe the average person to be like the simple hero of one of George Ade's stories who "was kicked in the head by a mule when very young and believed everything he read in the Sunday papers." Perhaps the generally prevalent underestimation of the public intelligence is responsible for our failure here as well as in connection with another potentially promising yet virtually unexplored cultural medium—the motion picture.

It might be urged that it is the duty of the schools to satisfy this want, but obvious difficulties exist: In the first place, a large number of the population can not take advantage of formal instruction because they do not have sufficient preparation, adequate time or the required funds. The survey courses in science which are finding their place in the curricula of more and more institutions of higher learning serve an admirable purpose in interpreting the spirit of scientific endeavor to college students who have had no previous scientific training, but they are at once unavailable to the great body of people who can not attend college.

Moreover, the hypothetical intelligent layman does not ask for *systematic* instruction. He wants, more often, immediate and intelligible answers to particular questions which arise in his mind, usually through some everyday contact; and he insists that his information be vividly, simply and interestingly presented. Frequently he desires, too, an inkling of how science and scientists "get that way," *i.e.*, some idea of the spirit, methods and scope of science. The remaining part of the complete account—the story of the systematic structure of science and its orderly array of supporting facts—is something which must be administered deftly and unobtrusively, if at all.

It must be realized, of course, that we can not make of every layman a trained scientific investigator (nor would this be a very interesting world if we could!), but we can direct interest in science to gratifying ends. We need but recognize the fact that, besides having intrinsic "practical" worth, science can be looked upon as a cultural pursuit, deserving of a place alongside music, the

[1] See, for example, the letters by two of our leading scientific journalists in *Science*, June 14, 1935 (p. 591), and in the same journal for June 28, 1935 (p. 640).

drama, art, literature, etc., in the life of the individual—as a hobby, which it often was in its earlier history—quite apart from any professional or technical applications it may have. Indeed, according to Pearson,[2] "there is an insatiable desire in the human breast to resume in some short formula, some brief statement, the facts of human experience. . . . It leads civilized man . . . to express his emotional experience in works of art, and his physical and mental experience in the formulae or so-called laws of science. Both works of art and laws of science are the product of the creative imagination, both afford material for the gratification of the aesthetic judgment."

If, then, we face the fact that interest in science on the part of the people is beginning to manifest a sort of restless germination, and if we realize that neither the press nor the school is at present able to foster that interest adequately, how is the situation to be met? In order to answer this question, let us examine the means by which some other attributes of a cultural life are garnered. A love and appreciation of good music is, of course, fostered by hearing competent and artistic renditions of musical compositions; interest in art is developed and quickened by viewing actual works of art; the spirit of the drama is to be sought in representative plays interpreted by talented actors. Often we must be content with substitutes for these stimulating first-hand contacts: We listen to phonographic or radio renditions of music in place of enjoying the sparkling animation which only the concert hall can offer. Compare the satisfaction of perusing a pedantic treatise on the drama with witnessing an absorbing play well acted. Contrast the reading of a printed essay with listening to an eloquent, arresting speaker!

[2] Karl Pearson, "The Grammar of Science," Pt. I, p. 36, The Macmillan Company, 1911.

From all of this we may understand that the direct and vivid method of interpretation exemplified by the theater, the concert hall and the opera house—involving a simultaneous, coordinated appeal to both the visual and auditory senses—might prove the most effective means of presenting scientific material. By a long process of evolution, the theater has developed a spirit and method of portrayal which is basically well founded and effective. The psychology of the theater is essentially sound; the auditors come to be entertained—they are at once in a receptive mood. The physical devices of the ideal modern playhouse sustain and enhance this spirit; the skilful blending of form, color and music into a harmonious whole, the fusion of many arts to produce a pleasing effect—all these contribute to the success of the offering, whether its purpose be casual diversion or the transmission of an earnest message.

In order to adapt both the spirit and the physical equipment of the drama to the presentation of scientific information, it is proposed that a Theater of Science be established—a theater where, by means of extensive demonstrations, the chief rôles are played by natural phenomena and where the laws of nature may be seen in intimate "personal appearance."[3] Otherwise expressed, the science theater would stand in the same relation to all science and technology as the planetarium does to astronomy.

In a large city or center of population, a building would be erected to house the auditorium, preparation rooms, apparatus storehouse, shops, library, conference rooms and offices. The theater audi-

[3] While these views are here expressed in the language of the theater, this type of presentation is not to be confused with dramatic offerings or motion picture plays based upon episodes in the lives of great scientists, although such have often been suggested and some examples have actually appeared. Consult Benjamin C. Gruenberg, "Science and the Public Mind," pp. 127–8, The McGraw-Hill Book Company, 1935.

torium must have upon its stage highly adaptable lecture and demonstration tables fully equipped with those features found in modern university science lecture halls and with certain others made necessary by the peculiar requirements of the present endeavor. Running water, compressed air, compressed oxygen, illuminating gas and electric current at various voltages and frequencies should be available.

The apparatus used in conjunction with demonstration lectures is to be assembled in preparation rooms flanking the lecture platform. If lectures are to follow one another at rather short intervals—and this is almost a necessity if building and equipment are to be utilized to best advantage—a revolving stage would be highly desirable, so that one lecture might be set up on the rear section of the stage while another is in progress on the side facing the auditorium. Revolving stage installations in several American and European playhouses are operating with success and contribute effectively to the enjoyment of the performance by shortening *entr'actes* and by permitting of novel effects otherwise impossible.[4] Air conditioning of the auditorium would not only contribute to the comfort of the audience but would be of decided value with respect to the successful operation of the demonstrations, *e.g.*, humidity control for electrostatic experiments.

Visual aids are, of course, of utmost importance here and must be available in every required form. Provision should be made for the effective display of charts and graphs, and there must be complete projection equipment for standard sound motion pictures[5] and for slides. A useful addition to the projection lantern is an attachment for opaque projection of geological specimens, etc. A microprojector is indispensable, especially in conjunction with lectures in biology.

Demonstration apparatus for use in the science theater must be selected with great care and with regard for simplicity. The present tendency appears to be to make a piece of apparatus bristle with vacuum tubes and photocells, but these highly sophisticated impedimenta serve only to obscure the basic simplicity of the phenomena to be shown. Besides being severely simple, the apparatus should be designed in a way which makes it easily visible to a large audience. Apparatus built for ordinary laboratory use may be inadequate in certain instances, requiring special constructions of "heroic" size.

Far more important to the success of this venture than plant and equipment is the type of lecture offered in the Theater of Science. The cardinal principle is the fact that the lectures are for the benefit of the layman and not for the trained scientist—indeed, in no case must any previous special knowledge, training or background be presupposed. In the words of the late Edwin E. Slosson, the first director of Science Service,[6] the expositor must "weave in" the background as he goes along. The lectures must always be entertaining and of human interest and—in a legitimate sense—spectacular. Their aim must be to convey something of the spirit and methods of science rather than a mass of detailed information. The presentations should be

[4] See, for example, Irving Pichel, "Modern Theatres," New York: Harcourt Brace and Company, 1925.

[5] These may be used in connection with certain lectures where suitable film subjects are at hand. A reasonably complete selection of such films does not yet exist. For more advanced auditors, however, subjects such as those made cooperatively by The University of Chicago and the Erpi Pictures Consultants of New York are obtainable. See H. B. Lemon in *Journal of the Society of Motion Picture Engineers*, pp. 62–67, January, 1934.

[6] A highly reputable press service, with headquarters in Washington, D. C., supplying accurate science news to many of the country's leading newspapers, and publishing the weekly *Science News Letter*.

accurate, definite and informative, but not necessarily systematic. Any actual instruction which the audience receives will be obtained in the guise of entertainment. The publicity material should stress this point by billing the lectures as "entertainments," and auditors should be left to discover for themselves the substantial content and value of the lectures without being continually reminded that they are to be "uplifted" or "inspired." To label these lectures explicitly "cultural" would be fatal. Millions who viewed the excellent science exhibits at the recent Century of Progress Exposition in Chicago found them absorbingly interesting and came away feeling that they had had a good time. They were not stampeded into attending, and science, on its own merits—competed successfully with the great variety of other "entertainment" offered at the exposition.

The regular lectures are intended to appeal to the average adult. However, it may be desirable to offer afternoon lectures for juvenile audiences as well.[7] School children of to-day exhibit an eager inquisitiveness regarding science and technology, and it is fully as important to nurture and develop their interest in this instant as it is to awaken and to guide interest in art, music and literature in early childhood.

To those whose curiosity regarding particular topics is sufficiently aroused, bibliographies of graded reading and study might be supplied. Works to which reference is made would be available in the library of the building.

The initial costs of this undertaking might be met by funds contributed by the local, state or national governments, by popular subscription, by individual donors, or by a combination of these sources. In all likelihood, operating costs could be met adequately by charging a small admission fee. A plan involving course tickets at a reduced rate and life memberships, including a subscription to a reputable popular science periodical, also suggests itself.

It is entirely feasible for any city of sufficient size to have a Theater of Science—a source of wholesome entertainment and diversion, a refuge from the strife and bickering of a chaotic world, a fountainhead of inspiration where, in time of trouble, one may take comfort in the immutability and steadfast permanence of eon-old natural laws, a means of turning from vexing thoughts and laborious mundane pursuits to something which occupies the mind, stirs the imagination and inspires courage for the future.

[7] Similar, for example, to the famous Christmas Lectures at the Royal Institution in London.

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THE DEPRESSION AND MENTAL DISEASE

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ALMOST every one is certain that he understands himself very well and the actions and conversation of most other people fairly well. But when we and our friends fail to understand the actions of a man we usually call that not-understood man crazy. In other words, we say a person is suffering from mental disease when his behavior and conversation seem to us illogical, irrational or inappropriate. We are frequently unable to reason with this man in the terms of everyday common sense. Most often the person himself does not realize his condition, but if he does, he usually says that somehow he has lost control of his thoughts or actions. A word of caution should be made here, namely, that we do not regard as diseases the minor eccentricities of everyday life, such as individual oddness, hysterics, temper tantrums or similar peculiarities. These ordinary exhibitions of temporary unreasonableness, although similar to the behavior of the insane, are after all either temporary or they do not seriously interfere with a man's everyday life.

Since the person we call insane can not tell us why he acts as he does and since in most cases we find no physical trouble which might be responsible for the behavior, we have been in the habit of thinking that insanity is caused by circumstances such as grief, disappointment, unrequited love, loss of employment or savings, physical injury or by general mental stress. Any or all of these may have happened before the disease began; hence it is easy to say they are the reason for the insanity. Because of things the patient may have said, the way in which he behaves or the kind of person he was before he became sick they are easily accepted as reasons. They are all circumstances which every one can understand and which in the absence of any evidence to the contrary are considered acceptable explanations.

Essentially then, common sense holds that undue, prolonged mental stress leads to insanity. Most unwillingly and unwittingly we have been going through a practical test of this popular theory. We are slowly emerging from a severe economic depression and are still in the midst of a social revolution. The increased unemployment, the wage reductions, the loss of savings, together with the sense of social and economic insecurity of the past six years have brought an ever present mental stress, a feeling of insecurity and of tense unhappiness. Certainly in the face of this stress the number of persons suffering from mental disease must have sharply increased, if the common-sense explanation is correct.

The social and economic importance of this problem is further emphasized when one remembers that for several years past almost half of the hospital beds in the United States have been occupied by patients suffering from nervous and mental diseases. Since most of these patients have no means of self-support, this burden represents one of the large items in American governmental budgets.

Fortunately, accurate and adequate statistical reports of occurrence of mental disease have been published annually

for the past twenty-two years by the state of New York. These New York State figures are representative and typical of the condition as it has existed in every one of the states. A first examination of these reports shows that 6,300 new cases were admitted to all the New York State mental hospitals in 1912, while about 12,000 cases were admitted in 1934. This is an apparent increase of 87 per cent. But we must remember that the general population has also increased between these years. If we allow for this general population increase by basing our figures on the number of cases per 100,000 population, then we find that the rate was 67 in 1912 and 86 in 1934, an increase of 27 per cent. This is for all mental hospitals in the state of New York, both private and state, and includes all cases, regardless of diagnosis, admitted to mental hospitals for the first time.

At first thought many have been inclined to attribute this increase of 27 per cent. in mental disease to the increase in the complexity and tension of present-day life. However, when we examine the figures more carefully and separately study each variety of mental disease, we find, much to our surprise, that for all kinds of mental diseases, save one, the number of cases per 100,000 has remained remarkably constant for the past 22 years. This one disease that has increased in prevalence is known as cerebro-arteriosclerosis. It is a condition brought about by hardening of the blood vessels of the brain occurring almost entirely in people over 45 years of age. The rate for patients sent to mental hospitals on account of this disease has increased from less than 2 per 100,000 in 1912 to over 14 per 100,000 in 1934, an increase of almost 700 per cent. in 22 years. I am inclined to think that this tremendous increase is mostly, though not entirely, due to the fact that during the past quarter century there has been a gradual and consistent increase in the per cent. of total population who are old enough to develop cerebro-arteriosclerosis. In 1912, for example, less than 21 per cent. of the New York State population were over 45 years of age. In 1934 this figure had increased to almost 25 per cent. In brief, individuals 45 years of age or over accounted for one fifth of the general population in 1912 and for one fourth of the population in 1934.

This increase in the number of people over 45 is mainly due to public health work and preventive medicine, which has added more than 10 years to the life span of the average American citizen since 1900. Many people who 50 years ago would have died of appendicitis, typhoid, diphtheria, or the like, during their twenties or thirties, are now living to reach the age when they are susceptible to arteriosclerosis.

If we make a fair allowance for the arteriosclerotic and senile cases now being admitted to our hospitals, we find that the apparent increase of 27 per cent. in mental diseases during the past 22 years has dropped to an apparent increase of about 8 per cent.

It is highly questionable whether even this slight increase of 8 per cent. of hospital admissions is a true increase of frequency of occurrence. Certainly we must allow for the increased number of people who live in cities and for the continued development of more adequate hospital facilities. With respect to the first factor, it has long been pointed out that the number of hospital cases for most of both physical and mental diseases is considerably higher for the city than for the country. In general, the number of urban mental hospital cases exceeds the rural at a ratio of 3 to 2. In part this is due to such things as the greater utilization of hospitals and clinics by city dwellers or to the greater difficulty of caring for the mentally ill in a city apartment. Undoubtedly the apparent increase of 8 per cent. in mental disease is partly due to the fact that in 1934 the cities of New York State ac-

counted for 84 per cent. of the total population, as compared with less than 80 per cent. in 1912.

There remains to be considered the factor of available hospital facilities. In 1912 there were in New York State about 370 beds available per 100,000 population for mental disease patients, while in 1934 there were over 600, an increase of about 64 per cent. Since obviously the mental hospital population is partly dependent on the available hospital facilities, the large increase in number of hospital beds has contributed to the slight apparent increase in mental disease rate.

If we again return to the statistical reports and compare the rates for 1928, a year of prosperity, with 1932, a year of marked economic depression, we find that the rate of admissions to mental hospitals is practically the same, namely, 68.7 and 68.3 per 100,000 population when cerebro-arteriosclerosis is omitted from the computations. If we compare 1913, a year of peace and relative prosperity, with 1918, when the stress of the great war was at its height, we find that the corrected rates are identical, namely, 68 per 100,000 population.

In general, then, if we allow for the increased age of the general population, urban-rural rates and hospital facilities available, we find that we have a very constant rate of hospitalized mental disease which apparently is not affected by economic depression and its accompanying mental stress. I repeat, depression, financial insecurity, unemployment and general unrest have not led to any increase in hospitalized insanity. This does not mean that there has not been plenty of mental stress and anguish, plenty of ragged nerves and unhappiness, but these psychological stresses and tensions have not led to an increased rate of hospitalized mental disease.

If mental stress does not lead to mental disease, then why mental disease? It seems to me that from the evidence I have given, taken together with a vast amount of other relevant material, the conclusion is obvious that in spite of the mental symptoms, in spite of what the patient says, in spite of what relatives and friends say and in spite of the usual belief, the basis of mental disease is not to be found in the psychological stresses of economic depression or social unrest. The essential basis for the increased number of hospitalized mental patients is a population problem. Such factors as the increase in the general population, in the average age of our citizens and in the increased hospital facilities account for our present situation.

This does not mean that the mental side of the disease picture is unimportant. It is important that the patient suffering from any disease be kept in good spirits and as calm as possible. It is interesting, necessary and often vital to know and understand the mental life of the patient, but it seems to me that the study of mental life can only indirectly lead us to a sound understanding of the essential basis of the disease. For instance, we can tell from the behavior and mental processes of a man whether he has been drugged by morphine or alcohol. A skilled physician can frequently differentiate various physical diseases on the basis of the behavior and conversation of the patient, even when the illness is not mentioned. So the study of the psychological life of the patient may lead on to a better understanding of underlying constitutional factors which must be the essential basis of mental disease.

To sum up, insanity is popularly supposed to follow or to be the result of a generally increased mental stress and tension. This is not so! An examination of the records shows that although we have gone through a great war and three economic crises during the past 22 years, the rate of mental disease, when corrected for factors known to directly

affect it, has held remarkably constant with the exception of those diseases associated with old age. This increase in old age diseases we have attributed to the fact that after all a man must die of something and if typhoid does not take him at 30, cerebro-arteriosclerosis may at 60. The depression of itself has not led to any real increase in mental disease, in spite of the fact that it has undoubtedly increased mental stress and unhappiness.

WHY WE NEED WILD BIRDS AND MAMMALS

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There is an old maxim to the effect that "familiarity breeds contempt." In my mind, nothing more clearly illustrates the truth of this statement than man's varying attitude toward nature. There was a time when human beings knew so little of nature that they invested everything about them with a mysterious, even spiritual significance, and frequently did not dare to kill certain living things for fear that nature would visit vengeance upon them. In recent centuries, however, man has become more familiar with the workings of nature, and at the same time, seemingly in consequence of this familiarity, well-nigh contemptuous. Where primitive men avoided conflicts with nature because of ignorance and superstition, modern men sometimes go out of their way to fight nature, because they have learned enough to drop superstition but have not yet acquired anywhere nearly complete understanding, such as should bring respect for her complicated and, on the whole, beneficent ways.

It is because of this disrespect that vast forests have been destroyed, and that hillsides and valleys have been unwisely denuded of their natural cover. It is because of this attitude, too, that many types of animals have become extinct, or are approaching extinction—certain of our most prized kinds of fur-bearing animals, several kinds of wild ducks and geese, the passenger pigeon and the great California condor.

Too often have human beings suffered by reason of their ignorance of the scheme of nature. Blinded by immediate expediencies we have failed to foresee the effects of destructive operations against nature. Immediate profit has seemed more important than future welfare. Temporarily practical considerations are given right-of-way over permanent cultural benefits. All this, because we fail to perceive the whole of what nature provides.

It would be foolish to propose, of course, that nature should be allowed to remain absolutely undisturbed. For in our own presence anywhere we impinge upon natural conditions. But it is only common sense to urge that such disturbances as are really necessary be undertaken only with as complete an understanding of the situation as possible, and hence only as following upon studious observations of the most comprehensive sort. When crop protection makes local action against certain rodents advisable, it should not be forgotten that burrowing animals on uncultivated lands perform an important function in developing and maintaining the soil. Every effort should be made to limit destruction to a minimum, for wildlife is an asset to us not only from the obviously practical view-points of the farmer, the sportsman

and the water conservationist, but from those more subtle aspects apparent to the vacation-seeker and the nature-lover.

With each passing year we reach a clearer understanding of the complexity of nature. Through the patient work of field biologists and nature students, new factors in the relationship between wildlife and human affairs are constantly coming to light. As an example of what I mean I am going to tell you of an experience I recently had.

The second week of last October found me in the Sierra Nevada of California, walking along the main road which leads up the mountainside into Sequoia National Park. As the morning sunshine began to increase the warmth and dryness of the atmosphere, I noted the sound of falling and bouncing acorns of the black oaks which were just then yielding their annual crop. The slope was steep; and along about ten o'clock the sound and sight of descending acorns was impressive. They were even accumulating in little windrows along the inside of the road next to the bank; and now and then, one from far up-slope, having gained extra momentum, bounced clear over the road and proceeded on its way toward the canyon bottom below.

Acorns are smooth-shelled, heavy objects, and those of the black oak in particular are of rotund shape. These qualities make them insecure on any slope upon which they fall, until in their movements they reach some crevice or sufficiently wide strip of level ground on which to find lodgment.

It was clear to me that the direction of seed scattering from any one oak tree was well-nigh directly down-hill. In that place and on that day I saw *no* acorn moving *up*-hill. Gravity alone acted as the agency of distribution. There appeared no possibility of wind as an agent of elevation, as with seeds of such trees as maple, cottonwood and willow. In the case of the oaks, it might therefore seem, the only possible direction of general forest spreading through time would have to be, through the action of gravity and streams of water, always down-hill. But how, then, could forests ever have spread, naturally, so as to gain altitude on our many mountainsides?

The next two days, I spent a little to the westward, at about 1,000 feet altitude, in the valley of the lower Kaweah River, where another kind of oak, the blue-oak, abounded. Here I became aware of the presence and especially of the activity of certain birds, the jays. This activity, when looked into, became of deep significance; for here was the agency, at this particular place at this particular time, of transportation of acorns up-hill. The jays centered their interest in those most abundantly fruiting trees down in the bottom of the canyon. There, from morning to evening, they were gathering the acorns and carrying them up the slopes, to be ensconced in various hidey-holes, some of them to be buried, after the well-known blue-jay tradition, in the ground on the hillsides.

Every bird going up-slope bore an acorn lengthwise in its bill; every bird in return course was empty-billed. If I had only thought of it, here was a chance for counting birds, and their loads, in sight, during say, a three-hour period; and then computing the bushels of blue-oak acorns being elevated by the birds perhaps hundreds of feet each October day in that one valley.

In this same locality I saw ground squirrels busily gathering acorns that had fallen to the ground, carrying them in various directions to their burrows or to their shelling stations. Twice I watched a ground squirrel climb up a blue oak to the larder of a group of California woodpeckers, filling its cheek pouches with the acorns they had gathered and stored, even though being attacked by the resentful birds. Then the squirrel would go precipitately down the trunk and off to its own cache in the ground.

Observations of the kind just cited, gathered into notebook and memory, from many parts of the West, have convinced me that certain birds and mammals constitute a paramount agency in the dispersal of oaks and many other trees and shrubs. My recollections bring into this credit column not only California jays, woodpeckers and ground squirrels, but also gray squirrels, red squirrels, chipmunks and wood rats, and Steller jays and band-tailed pigeons. In reflecting upon this matter, we can readily see that the relationship is of reciprocal benefit; for all these animal agents of seed dispersal are supplied by the oaks with food or shelter or nursery sites. The trees produce crops of nutritious seeds—each seed nutritious either to the prospective oaklet or to the animal that eats it—in vast excess of immediate seeding needs. There is enormous seeming extravagance on the part of the trees, far greater production of seeds than would be needed to provide for persistence of the species, if the species were of fixed geographic position through time. The point I wish to make is that in the long-time interests of the tree species, involving migration of the whole forest, there is value-received from this seeming over-production of acorns. It is not extravagance, but good investment.

At any time, catastrophe may overtake the fortunes of the oak forest. Fire may destroy all the growths on a given slope clear to the top of the ridge. Then quick recovery—early repopulation by the oaks—will likely be dependent upon the survival and germination of acorns previously buried by animals in open places, where the heat was least effective, as also upon the year-by-year marginal replanting processes just described. I think especially of California's great erosion-guarding and water-conserving chaparral belt, of which the live oaks and scrub oaks of several kinds are prominent constituents—and their constant animal attendants, the California jays and the dusky-footed wood rats.

There are many kinds of oaks in California, each largely limited to some favorable climatic or topographic situation. The result is that the different species of oak occur in rather sharply delimited belts. It is this fact that lends added importance to the seed-distributing activity of birds and mammals. For we know that during past millenniums the local climatic and topographic conditions have shifted time and time again through the gradual elevation or depression of the land. This means that tree species have had to move their habitat from one period to the next or die in a struggle against oncoming adverse conditions.

Allowing our imaginations free rein, can we not visualize entire forests slowly marching up-hill or down-hill or to one or another point of the compass? Of course, oaks do not literally uproot themselves and move bag and baggage. Some of them may live 300 years in one spot. But as the older trees die out, the exigencies of the environment determine where new trees will sprout and mature and may lead to a shifting of the entire belt. In the pageant of natural history, trees often have been forced, in this sense, to shift their positions or become extinct. Their ability to do this has depended upon the availability of some means of distributing seeds in the direction of a more favorable environment.

Here, then, is where a certain portion of the associated animal life has come into the service of the oak species. In the present era, with life-zones probably advancing northward, and up-slope, we can think of the successive belts of valley oaks, blue oaks, golden oaks, black oaks and huckleberry oaks, on our mountain-sides, as relying most especially for that part of their dispersal involving elevation entirely upon their bird and mam-

mal associates. The same sort of relation doubtless holds for hilly or mountainous territory throughout the United States.

This story, which I hope has illustrated for you the close interdependence which exists among some living things, is just one of scores that could be told. It is probably only one of hundreds that are yet to be discovered. If we are going to continue to live with nature in peace and safety to ourselves, this fact must ever be kept in mind. We need to return to an attitude of deep respect toward nature. The relationships which have been set up through the ages between wild birds, mammals and plants, in fact among all forms of life, can not be disturbed unless we are willing to accept the consequences—and these may be exceedingly serious for us. Where change in existing conditions appears to be unavoidable we should proceed with a caution befitting our inadequate knowledge of the forces with which we deal; and above all we should avoid the captious heedlessness that has characterized our exploitation of our surroundings so often in the recent past.

FOODS WE EAT AND WHY WE EAT THEM

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At the Pennsylvania State College we have a student dining room which the architect has designed as a Pennsylvania Dutch grill. Over the counter from which the foods are served there is inscribed in German script the Pennsylvania Dutch motto, "Sak mir was du esscht und Ich sak dir was du bisscht." This is the Pennsylvania Dutch equivalent for the old maxim, "Tell me what you eat and I will tell you what you are." A recent writer has paraphrased this maxim by saying, "Tell me what you eat and I'll tell you how old you are." He informs us that it is possible to divide the span of human life into eleven dietary or gastronomic ages, which fall in the following chronological order:

Age No. 1—Milk.
" " 2—Bread and milk.
3—Milk, eggs, bread and spinach.
4—Oat meal, bread and butter, green apples and all day suckers.
5—Ice cream soda and hot dogs.
6—Minute steak, fried potatoes, coffee and apple pie.
7—Bouillon, roast duck, scalloped potatoes, French rolls, creamed broccoli, fruit salad, divinity fudge and demi tasse.
8—Pate de foies gras, wiener schnitzel, potatoes parisienne, egg plant a l'opera, demi tasse and Roquefort cheese.
" " 9—Soft boiled eggs, toast and milk.
" " 10—Crackers and milk.
" " 11—Milk.

While it is clear that this writer was poking fun at our dietary inconsistencies, he was also emphasizing a very important dietary truth, *viz.*, that milk plays a very important part in giving us the proper start in life and that we instinctively revert to milk when we have reached the age when our digestive organs begin to show the results of unwise dietary excesses of former years.

Our knowledge of foods and food values has undergone many changes as a result of chemical and nutritional researches. Hippocrates (460–370 B.C.) believed that there were many kinds of food but that there was but one single substance in foods which was necessary for normal growth and development. As late as 1813 the eminent French physiologist, Richerand, still adhered to this hypothesis. Twenty years later (1833) Dr. William Beaumont published his classical work on gastric digestion and at that late date he referred to the nutritive value of foods in terms of a

single substance which he called "aliment." It would be very easy to solve our dietary problems if this theory could be shown to be correct. Unfortunately for the layman, each new discovery in food chemistry seems to make the problem more complex.

Dr. William Prout, an English physician, was one of the first scientists to "complicate the picture" when he announced in 1834 that foods contain at least three essential types of materials which are necessary for good nutrition. These substances were called albuminosa, oleosa and saccharosa, which are known to us as proteins, fats and carbohydrates.

Justus von Liebig, of Germany, was largely responsible for the conception that fats and carbohydrates are used largely as sources of heat and energy in the animal body, while proteins function primarily as building materials for body tissues.

As chemistry developed, foods were classified according to their content of these three substances, and the first feeding standards for humans and domestic animals were, naturally, chemical standards. The first period, therefore, might well be called the "chemical period" in nutrition. This was followed by a second period, which might be called the "energy period," in which food values were expressed in terms of calories or heat units. It was not long, however, before it became evident that diets could be compounded from chemically purified proteins, fats, carbohydrates and mineral salts, which conformed to the best of the chemical and energy feeding standards and yet lacked something necessary for normal growth and reproduction.

A new method of research was devised, using chemically purified diets and small experimental animals, with the result that a new (biological response) period came into existence. This period of research has led to what is popularly called the "Newer Knowledge of Nutrition." During this period three important types of discoveries were made, which have had considerable influence on the food habits of the American people.

Prior to this period chemists and nutritionists believed that all proteins, regardless of source, possessed the same nutritive value because they all contained about the same amount of nitrogen. The new work with small animals proved that this is not the case, since animals grow better on some proteins than they do on others. Subsequent investigations by the ever curious research chemist led to the discovery that proteins of high biological value contained many amino-acids (which act as building stones for body tissues), while the poorer proteins were found to be lacking in some of these amino-acids which were needed by the body tissues.

When the missing amino-acids were added to the inferior proteins or when other proteins were added to the diet, rats again grew normally. Thus, the first important lesson to be learned is that, as a class, individual animal proteins are nutritionally superior to individual vegetable proteins and that the wise mother will plan her meals in such a manner that her growing children will be certain to receive all the amino-acids necessary for the construction and repair of muscles and similar tissues. This can be done by supplementing the important energy-producing foods, such as bread and cereals with vegetables, milk, eggs and meat.

The second discovery that resulted from work with small animals had to do with the mineral salts in the diet. Scientists already knew, of course, that the growing child and even mature people must have mineral salts in order to construct strong bones and teeth and keep the blood and body fluids in healthy condition. They had the feeling, however, that the mineral problem "sort of took care of itself" if the other ingredients, such as proteins, fats and carbohydrates, were provided in ample amounts.

The biological response tests with small animals soon exploded this idea, for it

was found that some of our daily diets were woefully lacking in certain mineral or inorganic salts. This type of research also led to a better understanding of the individual functions of the common inorganic elements, such as calcium, phosphorus, magnesium, sodium, iron and chlorine. Much to our surprise we began to discover that some of the rarer elements, such as copper, iodine, manganese and even zinc, might be vitally essential for health and well-being. In former years copper was considered a member of the "poison family"—to be gastronomically avoided. Biological tests have shown, however, that copper in traces has a very beneficial effect on the utilization of iron and helps us to build better red blood cells.

It is entirely possible that we may find eventually that practically all the inorganic elements have a definite function to perform, in spite of the fact that they are present in almost infinitesimal traces. Iodine is a case in point. When it is absent from the soil, food crops and waters—such as we find in goitrous regions—excellent prophylactic results can be obtained by eating foods or drinking water containing very small quantities of iodine. Again the conclusion seems inevitable—that we are more likely to obtain the mineral salts we need, if we will vary our diet sufficiently to ensure a varied supply of mineral elements.

I have already pointed out that milk contains proteins of high nutritive value. Milk also contains a very desirable mixture of inorganic salts. In fact, milk is our best single source of calcium, and research has shown that it is quite difficult for the growing child to obtain its daily calcium requirement unless it receives from a pint to a quart of milk daily. It is not necessary to drink this amount of liquid milk to obtain this amount of calcium. It is possible to ingest a portion of the milk as dried or evaporated milk in cooked foods, puddings, etc. The vegetables, particularly the leafy vegetables, also contribute appreciable amounts of calcium and other valuable mineral elements, such as iron. Thus we have learned to drink more milk and eat more vegetables and fruits in order that our mineral salt supply may be adequate for normal health and well-being.

A third discovery that developed from animal experimentation was even more unexpected and unbelievable, *viz.*, the discovery of vitamins. It was found that some foods did not contain these mysterious chemical substances and if these foods were fed for long periods of time (without supplementation with other foods) animals ceased to grow, failed to reproduce and developed disease symptoms identical with or similar to human diseases that have been known by the medical profession for centuries. It was soon possible to produce experimental dietary diseases similar to if not identical with human beriberi, pellagra, rickets and scurvy. Then discoveries came so fast that even the research workers themselves had difficulty keeping up with the newest developments.

Vitamin A received considerable front page publicity because its absence from the diet caused loss of weight, respiratory diseases and blindness in rats, which could be prevented when milk, butter fat, egg yolk, fish liver oils, carrots or pigmented leafy plants were added to the diet. The world war presented an opportunity to test the value of rat experiments on humans because children in Rumania and Denmark were deprived of dairy products which resulted in pathological eye symptoms similar to those produced in vitamin A-deficient rats. When Denmark discovered that she was selling her milk and butter at the expense of the health of her children, she eliminated the eye disease by regulating the amount of dairy products that could be shipped from the country. In Rumania the problem was solved by administering cod liver oil to all children.

Brilliant researches of the past few years have shown that the yellow pig-

ment carotene, found in carrots and many plants, can be changed into vitamin A by the body tissues. The cow takes this pigment from her feed, changes a portion of it into colorless vitamin A and excretes the excess of yellow pigment in the milk, where it is available for us to transform it to vitamin A in our own tissues. Guernsey and Jersey cows can not change this pigment into colorless vitamin A quite so readily as the Holstein and Ayrshire breeds, with the result that butter fat from the former is more yellow than that from the latter, but the total biological values (from the standpoint of carotene and vitamin A) are equal, the former being richer in the provitamin, carotene, but poorer in colorless vitamin A. The reverse is true for Holstein and Ayrshire butter fats, since they contain more of the colorless vitamin A but less of the yellow carotene. Since Guernsey and Jersey milks usually contain higher percentages of butter fat, the total vitamin A effect of the milk may exceed that of the non-pigmented breeds. These are no longer mysterious substances, for we are now able to write the chemical formulae for vitamin A and for carotene.

Vitamin B or B_1 (anti-beriberi vitamin) has now been crystallized and its chemical formula is practically assured. This vitamin is necessary for normal health, appetite and growth and is found in cereals, yeast, milk, leafy vegetables and fruits.

Vitamin C is now being manufactured artificially by the pound, its chemical structure has been determined and the chemist calls it ascorbic acid. When we eat liberal amounts of oranges, lemons, tomatoes, fresh cabbage, lettuce and similar foods we are certain to obtain sufficient quantities of this scurvy-preventing vitamin.

An artificial type of vitamin D (known as activated ergosterol) has also been crystallized. It has been obtained in pure form and its chemical formula is known with a fair degree of certainty. This rickets-preventing vitamin is necessary for the proper building of bones and teeth in growing children. Our best natural sources are the fish liver oils. Milk does not contain it in satisfactory amounts, as a rule, which accounts for the fact that we find various types of vitamin D milk on sale which have been supplemented with various forms of vitamin D.

Vitamin E, the fertility or anti-sterility factor, will not be discussed because its clinical importance has not yet been fully established.

Vitamin G or B_2 promotes appetite and well-being. Without it a number of pathological conditions develop of which a pellagra-like skin disease is the most outstanding. We find this vitamin in many foods, such as yeast, whole cereals, milk, vegetables and fruits. Investigations of the past few months indicate that vitamin G (B_2) consists of two separate substances. One of these is a yellow pigment called "flavine" which is thought to be necessary for growth. The other fraction, tentatively called vitamin B_6, is thought to be specific in preventing and curing a dietary dermatitis in rats which is similar to pellagra in human beings. A number of other "B vitamins" have been suggested, but we have no information to date that they have any importance in human nutrition.

The newer knowledge of nutrition has taught us to be reasonably careful to supplement our daily diet of meat, bread and potatoes with the "protective foods," such as milk, eggs, fruits and vegetables. It is unwise and unscientific to condemn wholesome foods merely because they are lacking in certain dietary essentials. It is much safer and more economical from a health standpoint to supplement such foods with reasonable amounts of milk, eggs, vegetables and fruits.

EXCAVATION OF CRETACEOUS REPTILES IN ALABAMA[1]

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DURING the summer of 1933 there were found and excavated in Alabama two very fine and representative specimens of the upper Cretaceous Era. The first find was that of a giant marine *Protostega* turtle, and the second find was the terror of the Cretaceous seas, an unusually large *Mosasaurus.*

The first find was made near Eutaw, and the second find was near West Greene, both in Greene County. The stratum in which the fossils were found has been established by Dr. Walter B. Jones, state geologist, as the uppermost portion of the Selma formation of upper Cretaceous age. The layer at the place in which the excavations were made consisted of rotten limestone with a superimposed layer of drift or second bottom of the river. The turtle was found at a depth of six feet below the top-soil, on a washed spot, which from the numerous fossils found must have been a veritable cemetery of Cretaceous animals. The *Mosasaurus* was more propitiously located near the surface of the soil.

It is fortunate that both these animals were found, as they represent the most highly specialized aquatic forms of the era. They were also the most ferocious aquatic animals of the Cretaceous sea and were in most parts implacable enemies. On the bones of the turtle the evidence of the teeth marks of the carnivorous *Mosasaurus* show clearly that the animal either succumbed in a fight or was the prey after its natural death.

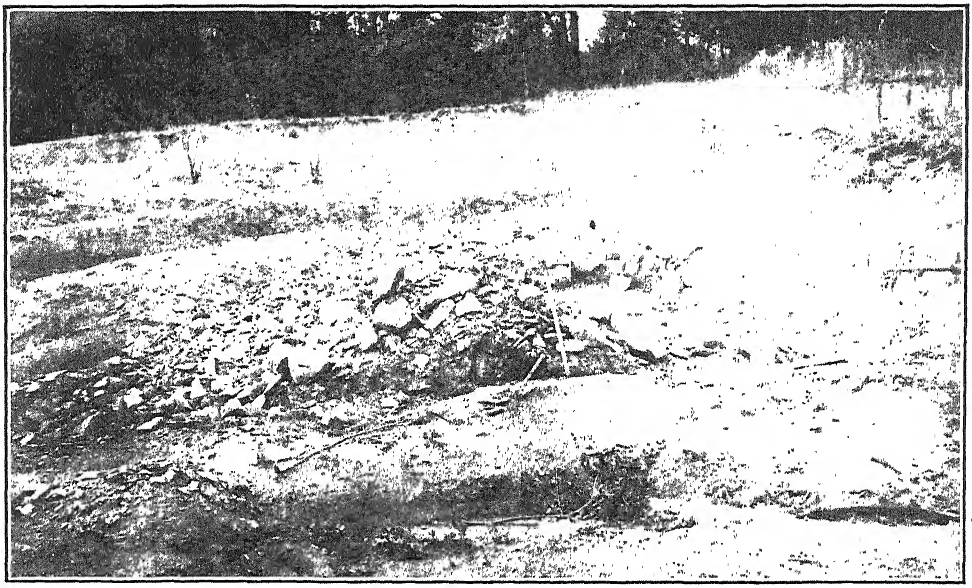
After the remains of the animal sank into the ooze at the bottom of the sea, and more sedimentary material fell on it, the bones of the turtle suffered breakage before petrifaction set in, and also further breakage and re-cementation after the fossils had been formed.

The fossils, after being repaired, assembled and restored, were identified by the writer as belonging to the order of reptiles known as *Chelonia* or *Testudinata,* and to the ancient family of sea turtles, *Protostegidae.*

No order of animals, that has persisted to this day, has a longer and more uneventful history than the order of *Chelonia;* and of none is the origin more obscure. If the turtles were not so familiar to us, or were entirely extinct as are nearly all the forms of life of that period, they would be considered the strangest of reptiles, and perhaps the strangest of vertebrates. It is the only animal that can hide its head and limbs under its ribs. The carapace or shell of the turtle is nothing more than the backbone and the dorsal and ventral ribs flattened and expanded and covered on the outside with heavy skin plates.

The evolution of the shell of the sea turtles is a progressive reduction of the bones of the carapace in adaptation to aquatic life. As the *Chelonia* of the Mesozoic Era reverted to water as their habitat, the need for a protective armor was less necessary than for those which remained on land; therefore, the continuous bony cover tended to disappear at the ribs and progressively receded toward the backbone. The *Protostegidae* is therefore a type that has been developed long after the turtles returned to the sea, as the greater part of the cara-

[1] Published by permission of the Geological Survey of Alabama.



Photograph by W. B. Jones

FIG. 1. EXCAVATING FOSSIL TURTLE NEAR EUTAW.

ABOUT TWO THIRDS OF THE ANIMAL HAD BEEN TAKEN OUT AT THE TIME THIS PHOTOGRAPH WAS TAKEN. THE HILLOCK AT THE LEFT FOREGROUND IS A BADLY BROKEN SPECIMEN OF NAUTILUS, *Pachydiscus Sp.*, SOME 30 INCHES IN DIAMETER.

pace and of the plastron are lost in this family. Also, the ribs are considerably flattened and consequently the usually greatly concave shell is depressed, a feature which aided in the aquatic forms and is another adaption to a sea life.

The modern leatherback turtle, a modification of the ancient sea turtle, in exceptional cases, attains the length of six feet. This size is only half that of the size of the specialized giant among the turtles of the upper Cretaceous.

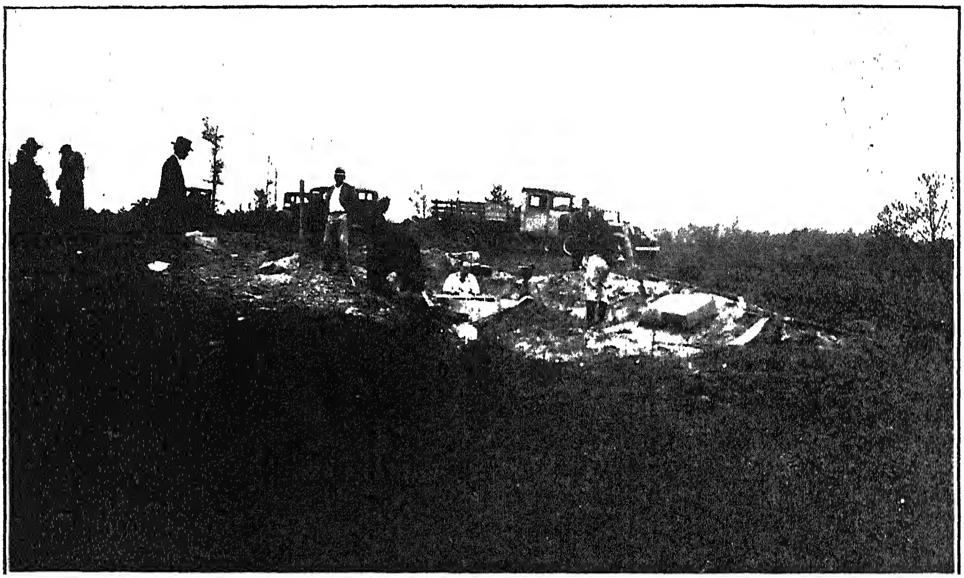
The measurements of some of the parts can best give a good picture of the turtle. The humerus or upper arm of the animal is 42 cm long; the radius is 25½ cm; the metacarpals and carpals, or wrist bones, are 14 cm; and the length of the finger bones and talons is 51 cm, making the total length of the outstretched front flipper 132 cm, or 4 feet and 4 inches. The span between the tips of the front flippers is 3 meters, or 9 feet and 10 inches. The length of the shell along the median line is nearly 5 feet. This animal, which had a flipper spread of nearly 10 feet, weighed about two and one half to three tons in its live state. It also had a formidable head, nearly 20 inches long, and equipped with an overhanging beak, six inches long and four inches wide.

The anatomical features of the giant turtle are very interesting, and from them several conjectures as to the animal's existence and mode of living can readily be deduced. The most conspicuous feature of the limbs is the size of the front flipper. The humerus is long and massive. The five digits are unusually long and supplied with strong long claws. Unlike all other aquatic vertebrates the turtles never developed real hyperphalangy. Naturally, the fingers were webbed; and, with the ectocondyle or muscle-attachment on the humerus, far down the shaft, it gave the *Proto-*

stega an oar-like organ for greater mechanical advantage in swimming. The flatness of the humerus and also the lowness of the radial crest and the expansive spread of the digits shows conclusively the adaptation to marine life. Although the turtle had great weight and a shape which was not very conducive to fast swimming, yet the indication of great musculature compensated for the bulk; and it must be assumed that the animal was a powerful and relatively fast swimmer. The rear flippers are smaller than the front and played a less important part in the locomotion of the *Protostega,* serving wholly as steering apparatus.

It is also a certain conjecture from the physiological processes of marine turtles, and from the fact that the remains of ancient turtles are found, as in this case, always in deposits which indicate shallow waters, that this type of turtle was a bottom-feeder and a littoral inhabitant.

The jaws with the massive premaxilla and the broad mandible were not only a good weapon of defense, but suggest an adept crusher of crustacea and mollusca. The abundance of shell-fish of that period afforded an almost inexhaustible source of food for the large turtle. The premaxilla is in the shape of a curved beak; such a feature would easily transform even a sluggish animal into a most formidable enemy.



Photograph by W. B. Jones

FIG. 2. OCCURRENCE OF THE *MOSASAURUS*

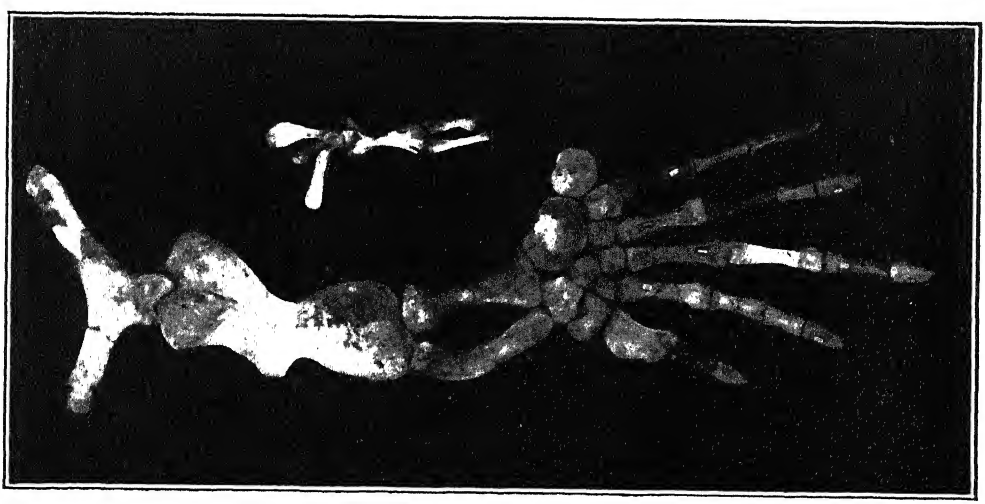
NEAR WEST GREENE. THE MAXIMUM COVER IS APPROXIMATELY SIX FEET.

In addition to the quality of a powerful swimmer, and an adequate defensive beak, the gigantic marine turtle had a protective carapace and plastron into which it could always withdraw its limbs and even partially the neck. Thus in the fight for existence the *Protostega* was well equipped to survive. In some battles the turtle may have lost a limb when very young; yet not be unable to survive and perhaps come out the victor over the *Mosasaurus,* the dread of the period. Dr. Wieland's "Archelon," a turtle 10 feet in diameter, is a classical example of the occurrence of such a battle and the

Photograph by W. B. Jones

FIG. 3. THE JAWS AND SKULL

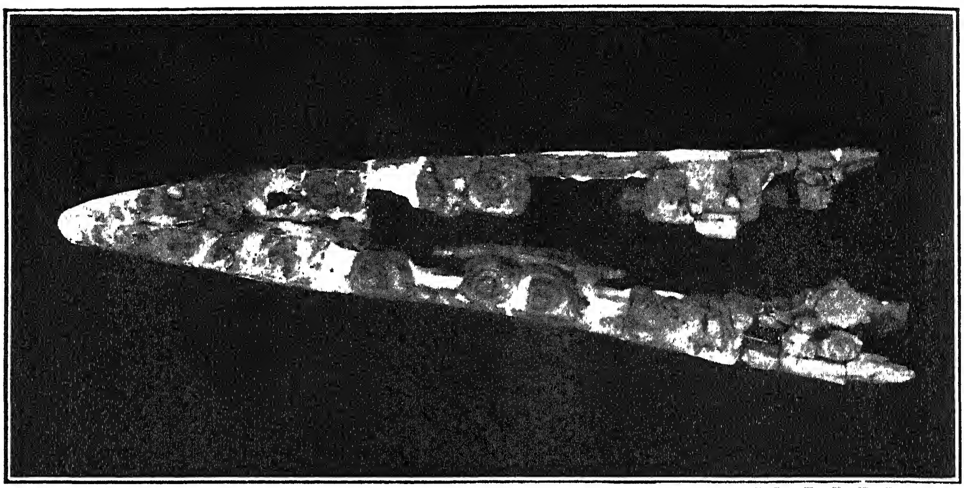
OF THE *Mosasaurus* BOXED AND READY FOR LOADING. THE JAWS EXTEND FROM CORNER TO CORNER.



Photograph by D. L. DeJarnette

FIG. 4. BONES OF RIGHT FRONT FLIPPER OF FOSSIL TURTLE

WITH COMPARATIVE BONES TAKEN FROM 140 POUND RECENT FRESH WATER TURTLE.



Photograph by D. L. DeJarnette

FIG. 5. PARTIALLY RESTORED UPPER JAW OF *MOSASAURUS*

SHOWING MASSIVE STRUCTURE OF JAW AND HEAVY TEETH.

turtle's survival after the loss of the rear right flipper.

In the classification of the fossils, it became apparent that the present specimen does not satisfactorily conform to all the genus characteristics of the *Protostega,* to which the specimen shows closest resemblance, nor do the ratios of the parts conform to the genus *Archelon.* The family is clearly established by the ribs forming the carapace, but the genus is still somewhat doubtful. Perhaps after full restoration of the skull is effected, the genus can be determined, which may also show it to be a new species.

In all events the present specimen is by far the largest fossil turtle of that type yet found, and is exceeded in size by only one specimen of a closely related form, that of the *Archelon ischyros Wieland* in the Yale Museum.

The *Mosasauridae* fossils, found in the same geological stratum, are of unusual interest to paleontology because of the singular anatomical structure of the head. The *Mosasaurus* is a short-necked marine lizard that lived in the shallow seas of the great chalk age, where it undoubtedly reigned supreme by virtue of its size and its ferocious and powerful jaws.

The head of the specimen found measures five feet, and the jaws comprise three fourths that length. The skull of this animal is about one sixth of the entire length. The relative size of the head to the body is indicative of predaceous and pugnacious habits of this sea lizard. It also indicates that the present skeleton is at least thirty-five feet long.

The upper and lower jaws are provided with numerous sharp conical teeth. Besides these there are also two rows of strong teeth implanted in the back part of the palate, on the pterygoidal bone; these are the throat teeth and are of great significance to the animal's feeding problem. The unique feature of the *Mosasaurus* is the conspicuous ball-and-socket joint in the middle of the lower jaw which permitted lateral flexing of the lower jaw. In this respect the mosasaur differs from all other reptiles, ancient or modern.

Besides the joint in the lower jaws, the tip of the lower jaws, at the point of symphyses, was loosely connected with ligaments. This flexibility was essential to the existence of this animal; for without any prehensible limbs, as in the modern lizards, nor with teeth adapted to tearing its prey apart, the mosasaur had to swallow its food whole.

The method of deglutition was very unique. The mosasaur seized its prey between the jaws, then extended the lower jaw by bending it laterally at the joint at the end of the splenial bone, and renewing its bite on the prey with the posterior teeth. By repeating this process the animal steadily pushed the food far enough back to be seized by the muscles of the fauces and the throat teeth.

Like all ancestral stock of the lizards the mosasaur had a pineal opening in the skull, but it is questionable whether it had a functional third eye, as in the *Rhyncocephlia* of to-day.

The paddle-like limbs of the mosasaur were adapted for aquatic life only. It may have moved in a serpentine way when accidentally stranded or while laying its eggs on the shore.

The assembled limbs of the turtle are now on exhibit in the Alabama Museum of Natural History, University, Alabama; and the skull of the mosasaur is in the process of reconstruction (see Figs. 4 and 5). Of the mosasaur, only seventeen feet of the skeleton have been removed so far, and the remaining part will, it is hoped, be removed soon.

Pach Brothers

HENRY FAIRFIELD OSBORN

THE PROGRESS OF SCIENCE

HENRY FAIRFIELD OSBORN: AN APPRECIATION

Henry Fairfield Osborn, honorary president of the American Museum of Natural History, died "in harness" on Wednesday, November 6, 1935, at the age of seventy-eight years. He was reading his morning mail in his study at "Castle Rock," Garrison-on-Hudson, N. Y., and was preparing to put in another joyous day's work on the second volume of his monograph on the fossil Proboscidea, when, as his son said, "he just fell asleep." Thus an ideally quiet and peaceful ending came to a life which combined an amazing activity with unperturbed quietness and dignity.

His fifty-eight years of "research, observation and publication" left a deposit of some 940 published communications, ranging from brief articles to voluminous monographs; he dictated tens of thousands of letters and wrote by hand hundreds of others. In the numerous organizations in the development of which he was actively interested he was seldom long unheard.

The most important of his scientific writings were in the field of vertebrate paleontology, but the principles of evolution, the prehistory of man, the biography of great naturalists, eugenics and educational methods and ideals were always in or near the front rank of his teeming mind. His effect on other people was in general highly dynamic and in one way or another he directed, encouraged or materially aided a great many investigations, publications, exhibits or courses of instruction prepared by others.

During the course of his long career he was instructor and later professor of comparative anatomy at Princeton University, Da Costa professor of zoology and dean of the Faculty of Pure Science at Columbia University, founder, curator and honorary curator of the department of vertebrate paleontology at the American Museum of Natural History, and later president of that Museum. He was perhaps the leading spirit in the foundation of the New York Zoological Society and served for many years as chairman of its executive committee and later as its president. In Princeton, long after he had removed to New York, he was influential in many projects, notably the building of the new museum of geology and paleontology.

At the museum for a quarter of a century he presided easily and securely over a board of trustees that included such veritable giants as J. P. Morgan, Joseph H. Choate, George F. Baker and Cleveland H. Dodge.

In honor of Theodore Roosevelt, who was his boyhood companion and lifelong friend, Osborn, with somewhat of Aladdin's magic, conjured forth a huge memorial building of surpassing dignity and beauty.

The Museum of Natural History under his leadership added many great buildings to itself, nearly doubling its capacity, and filled its granaries almost to the bursting point with the plenteous harvest reaped by its naturalists and explorers.

The Royal Society of London welcomed him as a foreign member and so did a long series of other leading scientific societies in Europe, China, India, the United States, Mexico and South America. To him were awarded many beautiful gold medals and coveted prizes: the Darwin medal of the Royal Society of London, the Wollaston medal of the Geological Society of London, the *Prix Albert Gaudry* of the *Société géologique de France,* the medal of the Pasteur Institute of Paris, and many others abroad and at home. The oldest universities in

England and Scotland vied with the universities of his own country in bestowing upon him their highest honorary degrees.

Castle Rock was almost as important a center as the museum for the radiation of his influence. There he constantly entertained men of distinction from all parts of the world and the names inscribed in the Visitors' Book would be a roster of international science, art, philosophy and statesmanship for two generations. When the meeting of the International Congress of Zoology was held in New York, Professor Osborn chartered a river boat, took the entire congress up the river to Garrison, and with his brilliant wife, Lucretia Perry Osborn, entertained his guests at a memorable luncheon party at Castle Rock.

Now what manner of man was this, who governed so easily and maintained such a multitude of contacts and could yet find time to produce a prodigious mass of scientific and educational writings? How did he come by his power and serenity, his dignity, his benevolence, his steadfastness, his good humor, his quiet friendliness? Let it be admitted that even the lowest human intelligence is too complex to be accounted for historically, and that the growth of each self is a unique integration of actions and reactions to hereditary, physiological and environmental stimuli which it is difficult or impossible to untangle. Nevertheless, there are abundant historical data which at least indicate some of the leading influences to which Henry Fairfield Osborn in the course of his own development reacted as he did.

His father, William Henry Osborn, was a man of preeminent probity and ability, who reorganized and built up a great railroad system. A small incident related to me by Professor Osborn will perhaps serve to illustrate his father's quick resourcefulness. On one occasion when William Henry Osborn was returning from Europe the ship was held up so long at quarantine that he would almost inevitably be prevented from rejoining his family on Christmas eve. He therefore went below, borrowed an old hat, picked up a mail bag and threw it over his shoulders and walked to freedom down the plank to the mail-boat. The elder Osborn evidently had a sincere admiration for the grand manner in nature, in art and in architecture, for his friend, the famous artist F. S. Church, painted for him a great canvas of mountain scenery in the Andes and selected for him the exact spot in the highlands of the Hudson upon which he built the tower of Castle Rock. And from the wide stone platform there one can look outward upon a view of astonishing magnitude and sweep, with the broad curving river beneath and the granite mass of Storm King beyond.

Professor Osborn's mother, as I remember her, might almost have sat as the original of Whistler's famous portrait of his mother. She combined gentleness and quietness with firmness. She was untiring in good works and was the chief founder of the Virginia Day Nursery.

At Princeton the young Osborn was greatly influenced by Dr. McCosh. This remarkable man, who combined the Presbyterian religion and philosophy with a dry Scotch humor, was one of the first orthodox clergymen to accept the principle of evolution; he therefore actively encouraged the development of the departments of geology and biology. Under Dr. McCosh, Osborn began a series of studies upon the visualizing faculty of the mind, but this interest in introspective psychology soon led him to studies bearing on the evolution of the nervous system in the lower vertebrates. Probably it was from his more or less Calvinistic environment that Osborn derived that deep antipathy to the idea of fortuity or chance, which was to remain as an outstanding characteristic of his philosophy of evolution and made it im-

possible for him to accept natural selection in its Darwinian form.

Meanwhile the fame of the discoveries by Professor Marsh, of Yale University, and Professor Cope, of Philadelphia, of many gigantic extinct forms of animals in the great natural cemeteries of the West doubtless excited at Princeton not only keen interest but the spirit of emulation. Accordingly, the young Osborn, with his friend W. B. Scott and several others, under the general direction of Professor Guyot, conducted the Princeton Scientific Expedition of 1877 to the Bridger and Washakie Basins in Wyoming. This was the first of those great expeditions which both Scott and Osborn were destined to send out during the next half century. The year following the expedition (1878) was taken up in part by the working out of the fossils from their hard matrix and by the identification and description of the material.

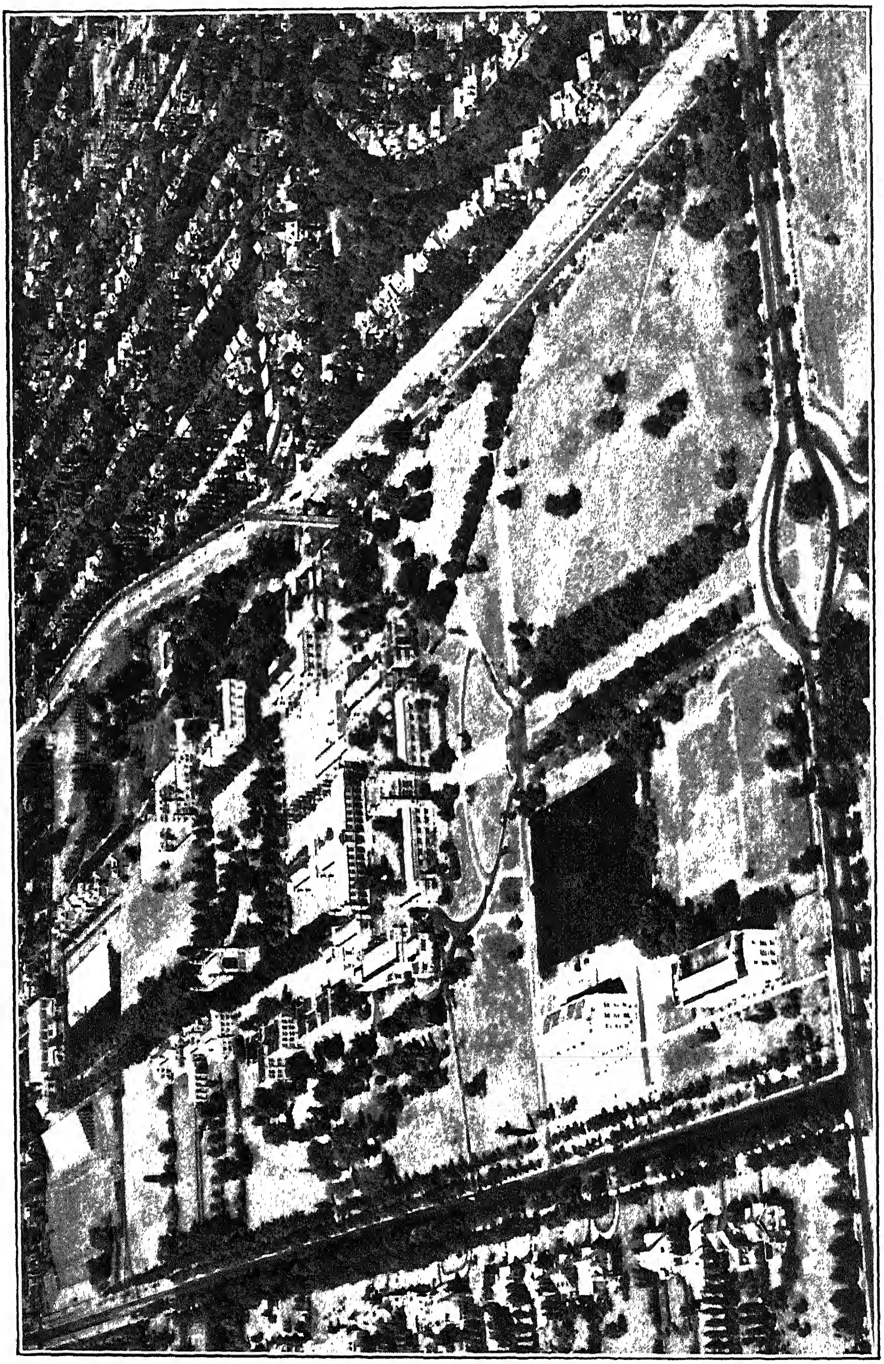
Doubtless at this time the two friends, Osborn and Scott, came to realize how meager was their equipment for satisfactory progress in either comparative anatomy or paleontology. In any case they wisely decided to study in Europe, Scott chiefly in Germany, Osborn in England.

Arriving in England in 1879 and entering Cambridge University for graduate study in zoology, Osborn found himself at the very source of many of the influences which he had felt in his home across the ocean. For now he was studying embryology at Cambridge under the direction of Francis Maitland Balfour; a little later at the Royal College of Science in London he attended the famous Huxley's lectures on comparative anatomy. One day Darwin himself came in to the laboratory and Huxley singled out the modest American youth, introduced him to the gentle and venerable Darwin and spoke of Osborn's promising work in the American Eocene. Soon afterward Osborn met Francis Galton and perhaps derived partly from him the springs of his later keen interest in human heredity and eugenics, for he collaborated with Galton in a paper, "Questions upon the Visualizing and Other Allied Faculties," and wrote a review of Galton's "Record of Family Faculties" when it was published in 1884.

Other important friendships for which he laid the foundations during his early days in England were those with Edward Poulton, of Oxford, with the Huxley family and with Leonard Darwin. The Princeton of 1877, in so far as it was dominated by Americans of English and Scotch descent, was practically an outpost of British culture and his own ancestry and upbringing predisposed him to appreciate and respond to the potent and ennobling ideals of the great Victorians.

But something more than all this contributed to his triumphal drive, continued for more than half a century and leading to wider and wider activities of organization, construction, administration and to scientific investigation, publication and education on a vast scale. Part of that something was his tireless and highly successful wife, Lucretia Perry Osborn, who was always his most ardent admirer and energetic partner. It was she also who sustained his spirit during periods of opposition and discouragement, and her death in 1930 deprived him of a powerful support. At the same time perhaps it intensified his passionate belief in the reality both of "creative evolution" and of the most essential features of modern Christianity. These he had derived from the days of his youth, and in all his writings on evolution, education and religion they are set forth with clearness and conviction. Doubtless his philosophy will be evaluated differently by those who view it from opposite poles; but it is clearly incumbent upon a student of his life history to set forth his philosophy along with his science.

William K. Gregory



AERIAL VIEW OF THE MAIN CAMPUS OF WASHINGTON UNIVERSITY

THE ST. LOUIS MEETING OF THE AMERICAN ASSOCIATION

Those who attended the last meeting of the American Association for the Advancement of Science, held in St. Louis some sixteen years ago, will, it is hoped, come again this year, if only to note the changes and improvements that have taken place. The conduct and programs of the meetings have improved progressively since 1919, and the prospects for the coming sessions are better than ever before. With the new Municipal Auditorium, St. Louis is now able to provide suitable accommodations for the special evening programs as well as various daily sessions, which were not possible even a few years ago. New buildings at St. Louis University and Washington University which will be used combine convenience and comfort to an extent which it is hoped will eliminate all recollection of the congestion and confusion that could not be avoided before they were available. The down-town hotels are in easy walking distance from the Auditorium, where registration will take place. The up-town hotels, headquarters for those using the two universities, are either close by or can easily be reached by car or bus.

This is not the place to discuss the program in detail. Preliminary notices in *Science* will list some of the outstanding features, and the final printed program will, as usual, give a full and complete account of the general and special sessions. At this time it can safely be predicted that the meetings will be outstanding, both because of the subjects discussed and the men who will participate. The mere mention of such outstanding speakers as Professor E. L. Thorndike, the retiring president, Dr. Karl F. Meyer, of the Hooper Foundation, San Francisco, Dr. Stanhope Bayne-Jones, of Yale, Dr. F. J. E. Woodbridge, of Columbia University, Professor Frederick Slocum, of Wesleyan University, Professor Vannevar Bush, of the Massachusetts Institute of Technology, Professor V. O. Knudsen, University of California at Los Angeles, Dr. J. B. Taylor, of the General Electric Company, Dr. E. H. Barbour, of the University of Nebraska, Dr. V. K. Zworykin, of the RKO Victor Company, Dr. H. G. Moulton, of the Brookings Institution, with a host of others, is sufficient guarantee of the high character of the meetings, as well as the universal appeal to all interested in science with its innumerable ramifications.

Aside from the general sessions and the meetings of sections and societies, a main attraction should be the scientific exhibits. These will be located in the Auditorium, with much more space available than is usually the case. Each year since the inception of these exhibits has shown an increased attendance and interest. Those not located in one of the large scientific centers are beginning to realize that on such an occasion an opportunity is afforded them to inspect and become familiar with apparatus and instruments of every kind; that books and supplies can be examined at first hand and the very latest advances in laboratory equipment are presented, with experts on hand to explain and demonstrate them. Quite apart from what may be regarded as the commercial side of the exhibition, there will be many special set-ups illustrating the advance in science in every field. Not only for the specialist but for the lay mind as well, many of these exhibits will prove of great interest.

For those who do not care to spend all day attending meetings St. Louis offers special attractions, some of which are not available elsewhere. The Jefferson Memorial not only houses some of the largest and most complete collections pertaining to historical events in the Mississippi Valley, but here are to be found the famous Lindbergh trophies; gifts, medals and souvenirs from thousands of sources, including a score of foreign countries.

Photograph by Bachrach

PROFESSOR EDWARD L. THORNDIKE,
RETIRING-PRESIDENT OF THE AMERICAN ASSOCIATION.

The Art Museum and the Zoo, each maintained as a civic enterprise through a mill tax, are located in Forest Park. This park, comprising some 1,400 acres, is one of the largest and most beautiful in America. Here in the summer season ten thousand people are able to enjoy each evening light opera in the unique municipal open-air theater.

St. Louis and Washington Universities, with their various schools and hospitals, need no special notice. They will both be used for meetings, and interested visitors will have ample opportunity to inspect them.

The principal attraction at the Missouri Botanical Garden will be a special orchid show staged for the occasion. The Garden possesses one of the largest collections of orchids to be found in any institution of its type. Some thirty thousand plants are housed at the Gray Summit Arboretum, a 1,600-acre tract now being developed. Blooming orchids are transported thirty-five miles from there to the floral display house in the Garden in St. Louis throughout the blooming season. While during the time of the meetings there will be nothing of interest to see out of doors, the various collections of palms, tropical plants, desert plants, etc., under glass, are always attractive.

With a splendid scientific program,

Photograph by Bachrach

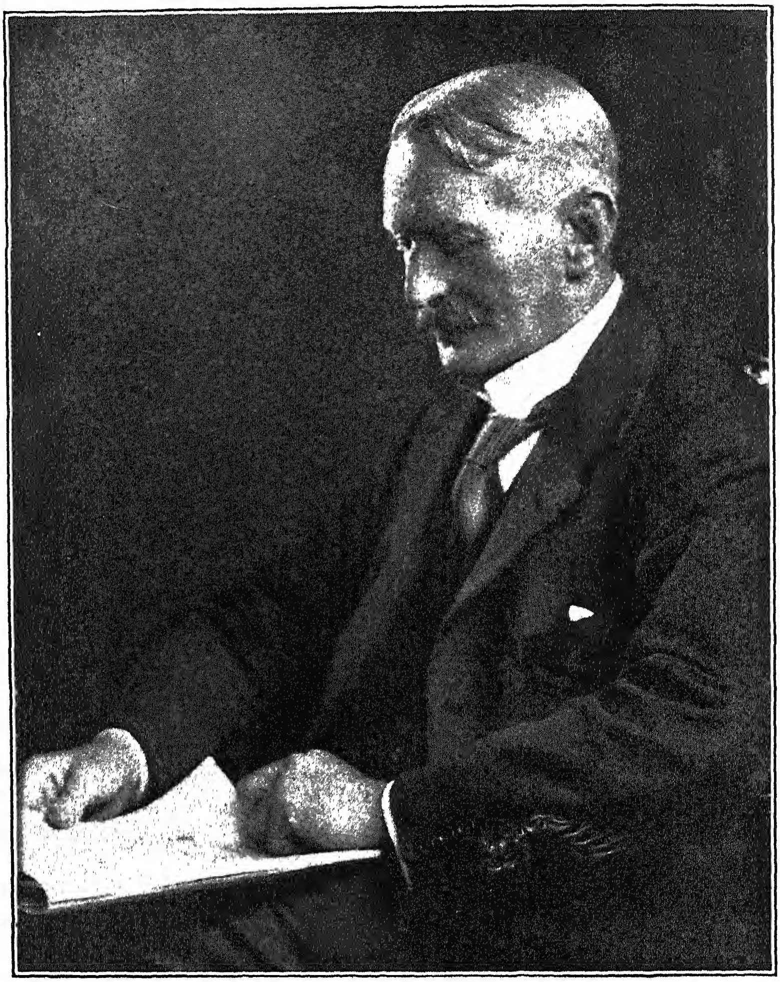
DR. KARL T. COMPTON,
PRESIDENT OF THE AMERICAN ASSOCIATION.

marked by outstanding contributors to the general sessions, and a complete scientific exhibit shown under adequate conditions, the success of the St. Louis meeting is assured. The added attractions of the city itself, with something to appeal to the most varied interest, should insure a record attendance. No effort will be spared by those in charge to make the St. Louis meeting of the association long and favorably remembered.

GEORGE T. MOORE, *Director*
MISSOURI BOTANICAL GARDEN

THE BRITISH ASSOCIATION AT NORWICH

THE meeting of the British Association which was held in Norwich from the 4th to the 11th of September last was by common consent no less successful and enjoyable than usual. There had been no previous meeting of the association in Norwich since 1868, and there was therefore little in the way of local experience to draw upon; but the association supplies its own precedents, and all the arrangements made by the local committees were admirable. The attendance of



PROFESSOR W. W. WATTS, F.R.S.,
PRESIDENT OF THE BRITISH ASSOCIATION.

members reached the number of 2,320, which was accounted satisfactory: it is only in larger cities, and in those possessing universities, that much larger attendances are to be expected. For the rest, there could scarcely be a more attractive center and area for a meeting of the association than that provided by Norwich and by East Anglia, of which Norwich is the ancient capital. The whole district is replete with scientific interest, in geology, geography, prehistoric archeology, botany, zoology, agriculture and other departments; and full advantage was taken by the sections interested in these subjects to make excursions and carry out field work. The city itself is historically one of the most interesting in all England, and members of the association freely availed themselves of opportunities for relaxation from scientific work by committing themselves to the expert guidance of local authorities who were at hand to show them many of the fine old buildings which Norwich possesses. The headquarters of the association (known as the Reception Room, where ticket business and the like are done and a common rendezvous is provided) were in St. Andrew's Hall, which is in fact the former fifteenth-century church of the Black

SIR JOSIAH STAMP, G.C.B., G.B.E.,
PRESIDENT-ELECT OF THE BRITISH ASSOCIATION.

Friars, long desecrated, but most wisely preserved in modern times as a public hall. The civic reception given to the members by the Lord Mayor and Lady Mayoress (Mr. and Mrs. Jewson) took place in the stately Norman castle which dominates the city from its high mound; it is now a museum, and a very fine one, to the scientific interests of which due attention was paid. The official Church of England service, attended by principal officers of the association, was held in one of England's most beautiful ancient cathedrals. The association has not often such a setting as Norwich for its meetings.

At the inaugural meeting the president, Professor W. W. Watts, F.R.S., dealt in his address with the subject of form, drift and rhythm of the continents. He was supported on the platform by four past presidents of the association in Lord Rutherford, Sir Arthur Keith, Sir Thomas Holland and Sir James Jeans; but he had to refer to no less than four others who within the year since the previous meeting had been lost to the association: these were the late Sir Edward Sharpey-Schafer, Sir Arthur Schuster, Sir Horace Lamb and Sir Alfred Ewing. On other evenings during the meeting there were discourses by

Dr. S. J. Davies on Diesel engines in relation to coastwise shipping, and by Dr. C. S. Myers on the help of psychology in the choice of a career. Further, Norwich and East Anglia took advantage of a procedure which the council of the association is always ready to put into operation if called upon, namely, to appoint lecturers to address public audiences (not confined, that is, to members of the association), with the result that such lectures were given in Norwich itself and also in the neighboring towns of Cromer, Fakenham, Great Yarmouth, King's Lynn, Lowestoft and Thetford.

It is impossible to review within a few hundred words the whole of the sectional programs, with their three hundred addresses, discussions, lectures and papers. One aspect of general interest, however, is found in the increasingly strong demand by public opinion that the association should pay even more emphatic attention to the exposition of scientific developments which affect public welfare and social progress. This is an interesting and gratifying sign of the times. So well marked has this attitude toward the advancement of science now become, that the association was even upbraided in certain newspapers, after the meeting, for taking insufficient notice of it in drafting the programs. And yet among the sectional presidents' addresses there were Dr. J. A. Venn's on the financial and economic results of state control in agriculture; Professor G. Hickling's on recent research on coal; Professor J. G. Smith's on economic nationalism and foreign trade; Dr. A. W. Pickard-Cambridge's on education and freedom; Professor P. G. H. Boswell's on the preservation of sites of scientific interest in town and country planning. Among discussions and papers with a similar bearing there were a discussion on the herring problem, and others on economic aspects of diet, scientific management, television, the applications of science to the control of road traffic (in which engineers and psychologists made an unusual collaboration), hearing and aids to hearing and sugar-beet problems; and among demonstrations there were Dr. G. W. C. Kaye's experimental lecture on noise, one of industrial management films and one of physical education. It is not a bad record for one meeting. And the scientific interests of the community are not likely to be lost to sight next year, when the meeting will take place (from September 9 to 16) at Blackpool in Lancashire, one of the biggest places of public holiday resort in England, and when the president of the association will be Sir Josiah Stamp, G.C.B., G.B.E., an economist of international standing.

The centenary of Darwin's landing in the Galapagos Islands, which fell close to the time of the meeting, was duly celebrated by papers and a discussion on the birth of the hypothesis of the origin of species. The British Association, as is well known, has an honorable relationship with Darwin's memory through its possession of his house at Down, in Kent, which it acquired by the gift of Sir Buckston Browne, and maintains as a national memorial, open to the public. It was a happy incident of the Norwich meeting that during it the association received from Emeritus Professor Van Dyck one of the last letters (if not the last) written by Darwin, a few weeks before his death in 1882; this has now found an honored place in the collection at Down House. As for the Galapagos Islands, the association, with much satisfaction, received word of the intention of the Ecuadorian Government to create a nature reserve in the archipelago; the American efforts which have been made to this end are profoundly appreciated, and the association gave evidence of its willingness to lend any assistance within its power to the consummation of this most important scientific movement, by appointing representatives to cooperate with any committee which may be appointed on this side of the Atlantic in connection therewith.

O. J. R. Howarth,
Secretary.

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